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KETTLE CREEK WATERSHED

Surface Water Quality and Waste Loading Guidelines

March, 1976

Ontario
Ministry of the Environment

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Director
South Western Region

KETTLE CREEK WATERSHED

SURFACE WATER QUALITY

AND WASTE LOADING

GUIDELINES

SOUTHWESTERN REGION

TECHNICAL SUPPORT SECTION

MARCH, 1976

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SUMMARY AND RECOMMENDATIONS

In the summer of 1973, a study was conducted to document the water quality of Kettle Creek and to determine the waste assimilative capabilities of the stream downstream from St. Thomas. In 1975, a review of streamflow characteristics was conducted for drainage basins upstream from Belmont, Ford Company of Canada Limited, St. Thomas and Port Stanley. Water quality of Port Stanley Harbour and adjacent Lake Erie was also studied in a 3 day period in July of 1975. The ultimate goal of those efforts was to establish waste loading guidelines for each wastewater source compatible with provincial water quality guidelines to protect recognized water uses.

Briefly, the report illustrates that inadequate streamflow is available throughout the watershed to sufficiently dilute municipal or industrial wastes discharged continuously through the summer low-flow period. At Belmont on upper Kettle Creek and at the Ford Company of Canada Limited plant on Dodd Creek, background streamflow can be non-existent during the six-month interval from May to October. Below St. Thomas, design sewage flows are expected to exceed natural streamflow most of the time between June and October.

Because of these low streamflows, receiving waters were found to be unsuitable for most uses other than waste assimilation particularly on Dodd Creek downstream from the Ford Company of Canada Limited plant and on Kettle Creek downstream from St. Thomas. Dissolved oxygen concentrations failed

to meet the Ministry criterion of 5 mg/ℓ for 8 to 10 miles of Dodd Creek below the Ford Talbotville plant and at the majority of sampling points from St. Thomas to Port Stanley. Populations of aquatic organisms were seriously disrupted in both these reaches although recovery to upstream condition was complete at the mouth of Dodd Creek and upstream from the St. Thomas sewage treatment facilities.

The discharge from Kettle Creek did not noticeably affect the surface water quality of adjacent Lake Erie during the 1975 3-day survey. However, a survey of sediment quality in 1974 indicated that bottom sediments of Port Stanley Harbour were so highly enriched that open-water disposal in Lake Erie was discouraged.

To improve water quality where it was found to be degraded and to protect it in other areas where it was satisfactory, the following recommendations are made:

1. The Village of Belmont should alter its discharge mode from seasonal (spring and fall) to annual (spring) with total retention from May through October and continuous discharge at a rate equalling inflow from November through April.

2. The Ford Motor Company of Canada Limited Talbotville Assembly Plant should upgrade its treatment to reduce effluent concentrations of BOD_5 to 5 mg/ℓ and to include nitrification and chlorination. Further, to provide

adequate dilution of the treated wastes, streamflow should be augmented when necessary to ensure a 1:1 ratio of streamflow to sewage. The Company should investigate the operational and economic feasibility of obtaining this dilution water either from the Talbotville artery of the Elgin Area Water System or from the presently inactive White Oaks well field supervised by the City of London.

A pipeline to Lake Erie is perhaps the most suitable long-term alternative.

3. As a long-range solution to water quality problems in Kettle Creek downstream from St. Thomas, the City of St. Thomas should meet with the City of London to explore the possibility of the imminent development of a common sewage pipeline to Lake Erie to serve the future needs of both municipalities.

Meanwhile, the City should immediately upgrade its sewage treatment facilities to achieve nitrification of its effluent and to reduce BOD_5 concentrations to 5 mg/ℓ.

To protect downstream water uses during summer low-flow periods, provision should be made for effluent storage or low-flow augmentation when sewage flows exceed streamflow. Effluent storage would involve the construction of a waste retention lagoon some 265 acres in size at present design

while low flow augmentation would require the development of an upstream impoundment, probably on Dodd Creek.

Steps should be taken to reduce the frequency of by-passing untreated sewage during storm events. It is hoped that a continuation of the existing sewer separation program will help alleviate this problem.

4. The Village of Port Stanley should alter its discharge mode from seasonal (spring and fall) to annual (spring) with total retention from May through October and continuous discharge at a rate equalling inflow from November through April.

KETTLE CREEK WATERSHED - SURFACE WATER QUALITY AND WASTE LOADING GUIDELINES

INTRODUCTION

To define water quality and quantity characteristics of the Kettle Creek Watershed and the capability of the stream to accept treated wastes, a study was conducted during the summer of 1973. Particular emphasis was placed on reaches receiving wastes from the municipalities of St. Thomas, Belmont and Port Stanley where developmental pressures continue to be exerted and on Dodd Creek - a tributary receiving treated wastes from the Ford Motor Co. of Canada Ltd. plant. This report updates an unpublished survey conducted in 1966 by the Ontario Water Resources Commission which established preliminary organic loading guidelines solely for the City of St. Thomas and an interim report to the City of St. Thomas issued in 1974.

Also, the report documents the results of a brief survey of surface water quality in Port Stanley Harbour and adjacent Lake Erie conducted during the summer of 1975.

Water quality was determined by monitoring chemical, physical and bacteriological characteristics over a twenty-four or forty-eight hour interval. Response of aquatic life was documented through a study of fish and bottom fauna populations. Long-term streamflow data were utilized to define streamflow characteristics in the critical areas. Mathematical modelling

techniques provided a tool to predict the effects of various loadings on water quality. Acceptable loading guidelines designed to protect water uses of the stream are presented in this report.

WATERSHED DESCRIPTION AND WATER USE

WATERSHED DESCRIPTION

Kettle Creek originates at an elevation of 875 feet above sea level and flows roughly 25 miles from Whittaker Lake in a southerly direction to Lake Erie with an average gradient of approximately 9 feet per mile. The watershed drains roughly 168 square miles of predominantly agricultural land in Elgin and to a lesser extent, Middlesex Counties.

The upper portion of the watershed is drained by two major tributaries - Kettle Creek flowing southwesterly from the Belmont vicinity and Dodd Creek flowing southeasterly from the Talbotville area. These two branches join in St. Thomas. Because soils in the upper reaches are relatively impermeable clays, base flow in most streams is minimal and during prolonged dry periods, streamflow could be reduced essentially to zero.

Downstream from St. Thomas the stream enters the Norfolk Sand Plain and from St. Thomas to Port Stanley the river valley deepens to 125 feet at Port Stanley. The stream channel

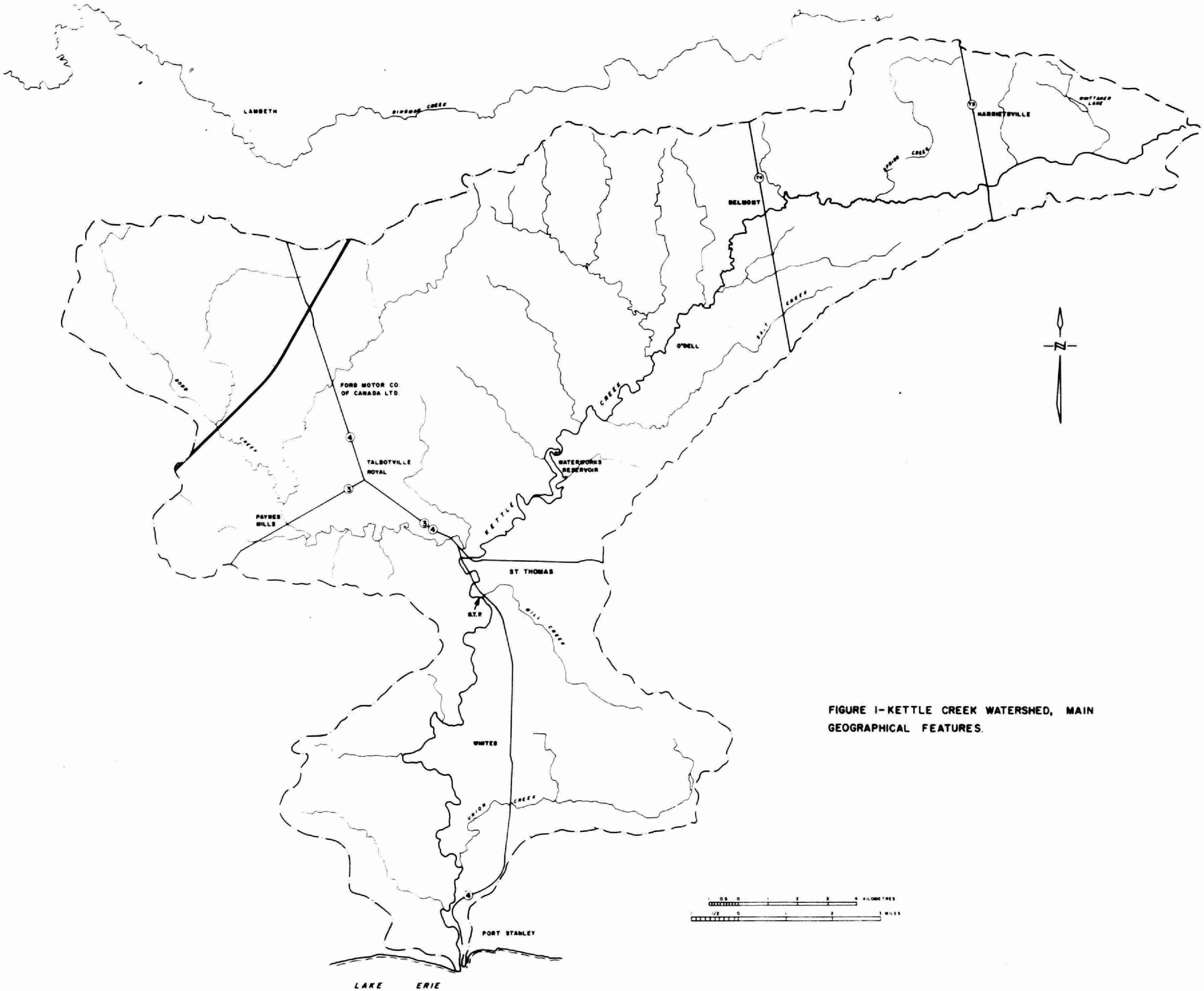

FIGURE I - KETTLE CREEK WATERSHED, MAIN GEOGRAPHICAL FEATURES.

cuts through surficial and shallow intermediate aquifers which are suspected to contribute base flow to lower Kettle Creek during dry weather conditions. Greatest base flow potential is found in the Union Creek-Whites area.

The mean annual precipitation at the St. Thomas meteorological station is 34.86 inches and the mean daily temperature for the month of July is 68.8^{O}F. The mean annual potential evapotranspiration is approximately 25 inches.

The City of St. Thomas is the largest urban centre in the watershed. Situated at the confluence of Dodd and Kettle Creeks, the city houses some 26,200 persons. Major industrial concerns include three metal-working firms and an iron foundry. Belmont (population 769) is located in the upper reaches of Kettle Creek. A dairy product plant is located in the Village. At the mouth of the stream is the Village of Port Stanley with a population of 1660 persons. The community is a summer resort and fishing village.

SURFACE WATER USE

The major use of Kettle Creek at present is for waste disposal. At Belmont, processing wastes from Borden Company Limited are land disposed although the .2 to .3 MIGD volume of uncontaminated cooling water is discharged directly to upper Kettle Creek. For treatment of municipal wastes, 16.2 acres of lagoons are being constructed which will be discharged twice

annually during periods of high streamflow. The Ford Motor Company of Canada Limited intermittently discharges approximately 700,000 gallons of treated wastes to Dodd Creek daily. Four 11-acre lagoons are designed to service a population of 4400 at Port Stanley. An annual spring discharge to Kettle Creek occurs from this treatment facility.

At St. Thomas, three activated sludge sewage treatment plants provide a combined secondary treatment capacity of 4.5 MIGD. Sewage flows between 4.5 MIGD and 10 MIGD receive primary treatment while combined flows greater than 10 MIGD are bypassed directly to Kettle Creek. Waste flows include processing wastes from metal-working industries and an iron foundry. From time to time, the Smith-Carr Drain and Caughill Drain have carried industrial wastes and storm and relief sewer discharges which have been known to cause water quality impairment during both dry and storm conditions.

Recreational use of the watershed is limited to Whittaker Lake and Union Creek where a number of private ponds are constructed on-stream. Water taking for industrial use or for irrigation purposes are authorized at eight locations mainly from streams tributary to lower Kettle Creek. At Port Stanley the creek mouth provides a sheltered harbour for pleasure boats and a commercial fishing fleet. Water use for the watering of livestock is scattered throughout the watershed. Lake species of fish such as channel catfish and silver bass migrate upstream and utilize the stream bed for spawning purposes.

METHODS

During 1973, field work involving around-the-clock collection of physical, chemical and bacteriological samples was conducted over 24 hours on upper Kettle Creek and Dodd Creek on July 10 and July 11 respectively. An intensive study extending over a 48 hour interval on August 1 and 2 was conducted on the reach from St. Thomas to Port Stanley. Aquatic invertebrates and fish were sampled from May 23 through June 24.

Samples were collected at twenty locations in Port Stanley Harbour and adjacent Lake Erie twice daily on July 26, 30 and 31, 1975.

Sampling sites for chemical, bacteriological and biological parameters are illustrated generally on Figure 2 and more specifically on Figures 3, 6 and 9.

Physical

Streamflow was measured during the survey using an Ott current meter while historical streamflow records were obtained from Federal stream gauging stations on Kettle Creek at St. Thomas (02GC002) and on Dingman Creek at Lambeth (02GE005). The 8 years of records at St. Thomas provide a documentation of daily streamflow data from a drainage area of 127 square miles. The data were used for loading studies at St. Thomas and pro-rated for use at Port Stanley. Owing to closer similarities in both topography and drainage areas, streamflow characteristics

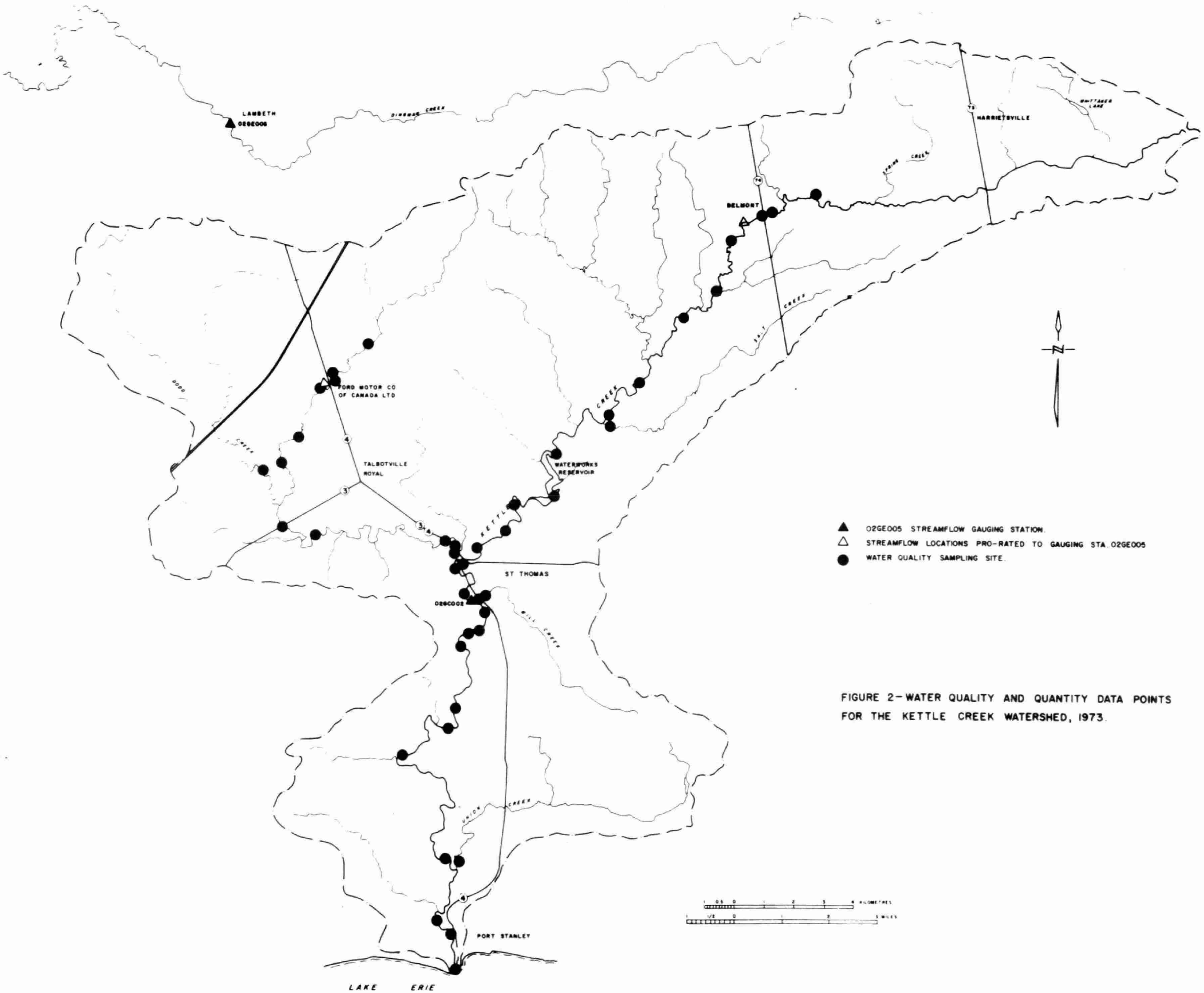

FIGURE 2 – WATER QUALITY AND QUANTITY DATA POINTS FOR THE KETTLE CREEK WATERSHED, 1973.

of Dodd Creek below Ford Company of Canada Limited and of upper Kettle Creek at Belmont were determined by pro-rating to records from the Dingman Creek gauge. Data were subjected to various statistical analyses to describe streamflow characteristics from year to year and distribution within each year. The mass curve analytical technique was applied to mean monthly streamflows at St. Thomas to determine the minimum storage volumes required to ensure proper assimilation of wastes based on the period of records.

Continuous precipitation records at St. Thomas were used to determine applicability of the short-term streamflow data at St. Thomas.

In the field, surface water temperatures were measured using a standard mercury hand thermometer and the temperature probe of a YSI-54 dissolved oxygen meter. Surface water samples for turbidity and volatile suspended solids were collected and analyzed at the Ministry of the Environment laboratory in London using standard procedures (Standard Methods, 13th Edition) or modifications of these procedures that have been adopted by this Ministry.

Chemical

Dissolved oxygen in surface water was measured in the field using a YSI-54 meter which was calibrated for each 3 hour sampling run against the Azide modification of the wet Winkler method. Grab samples were collected every six hours and analyzed

for BOD_5, nutrients, conductivity and chlorides at the London laboratory using standard analytical methods.

Bacteriological

Surface water samples were collected four times at 6 hour intervals on upper Kettle and Dodd Creek and 4 times at 9 hour intervals below St. Thomas. Samples were stored on ice and delivered to the London laboratory within 24 hours. Analyses conducted were total coliforms (TC), fecal coliforms (FC) and fecal streptococcus (FS) using the membrane filtration technique (MF) described in Standard Methods (13th Edition) with one exception; the media used to determine FC was MacConkey membrane broth (Oxoid).

Biological

To reflect longer term water quality and document effects on aquatic life, bottom-dwelling invertebrates were collected using a Surber Sampler. A square foot of stream bottom was sampled at stations selected on the basis of their physical similarity and organisms not represented in the Surber sample were taken from a variety of niches using a hand sieve. The benthic invertebrates were separated from debris, preserved in ethanol and returned to the London laboratory for enumeration and identification. The organisms collected were generally categorized as intolerant (stoneflies, mayflies, caddisflies), tolerant (leeches, sludgeworms) or facultative (all other forms) to facilitate presentation of findings.

Fish populations were assessed using a 30-foot bag seine at nine locations on Kettle Creek, six on Dodd Creek and one on Union Creek. Although most fish were identified in the field, specimens at some sites were preserved and identified at the laboratory.

Observations of aquatic weed growth and algal conditions were recorded at each station along with other pertinent field observations.

RESULTS

Detailed results of specific studies may be found in the Appendix. Salient facts have been extracted and are either presented for the watershed in general or considered in total for the three major reaches.

General

It was found from short-term continuous records of streamflow at St. Thomas that the low flow year was 1971 and that through comparison with long-term rainfall records that this is representative of a 1 in 12.5 year recurrence interval. This assumes that the low streamflow year corresponds with the low rainfall year. Records from 1968 through 1974 indicated that most runoff occurred in March through mid-April when 7 day mean flows fell within the 200 to 300 cfs range. From summer to early fall, flows averaged roughly 10 cfs with maximum 7 day means reaching 100 to 200 cfs. In late fall, median flows reached between 60 to 100 cfs.

Water temperatures measured during the survey were fairly stable over a 24 hour period ranging for the most part by 4 to 6°C. On the average, daily water temperatures were approximately 22 to 23°C for each survey reach.

Throughout the entire watershed, bacteriological guidelines for use of surface waters for livestock watering, irrigation and body contact recreation were exceeded.

A total of 22 different types of fish were taken during the survey including such game fish as smallmouth, largemouth and rock bass. Silver bass and channel catfish were among lake species captured. A total variety of 49 aquatic invertebrates were collected from the watershed.

Upper Kettle Creek (Belmont to St. Thomas)

Results of the analyses of pro-rated historical streamflow records for the 29 square mile drainage area at Belmont are presented in Table 1 of the text. The pro-rated mean monthly flow for Kettle Creek at Belmont shows that the greatest mean monthly runoff occurs in March with a discharge of 76 cfs. The minimum mean monthly flow occurs in September with a discharge of 3 cfs. The mean monthly flow from December to April is 35 cfs or above whereas from July to October the mean monthly flow is 7 cfs or less.

The minimum monthly mean with a 1 in 10 year return interval is 20 cfs for April and 41 cfs for March although the

Table 1 - Monthly streamflow data for Kettle Creek at Belmont.

MONTH	MEAN MONTHLY FLOWS (cfs)	MINIMUM MONTHLY AVERAGE FLOW WITH A RECURRENCE INTERVAL OF 1 IN 10 YEARS (cfs)
January	36	6
February	37	6
March	76	41
April	47	20
May	23	5
June	13	2
July	6	1
August	5	1
September	3	1
October	7	1
November	27	6
December	35	6

Note: Drainage Area : 29 square miles
Gauge : Pro-rated from 02GE005 (Dingman Creek at Lambeth)
Years of record : 1966-1974

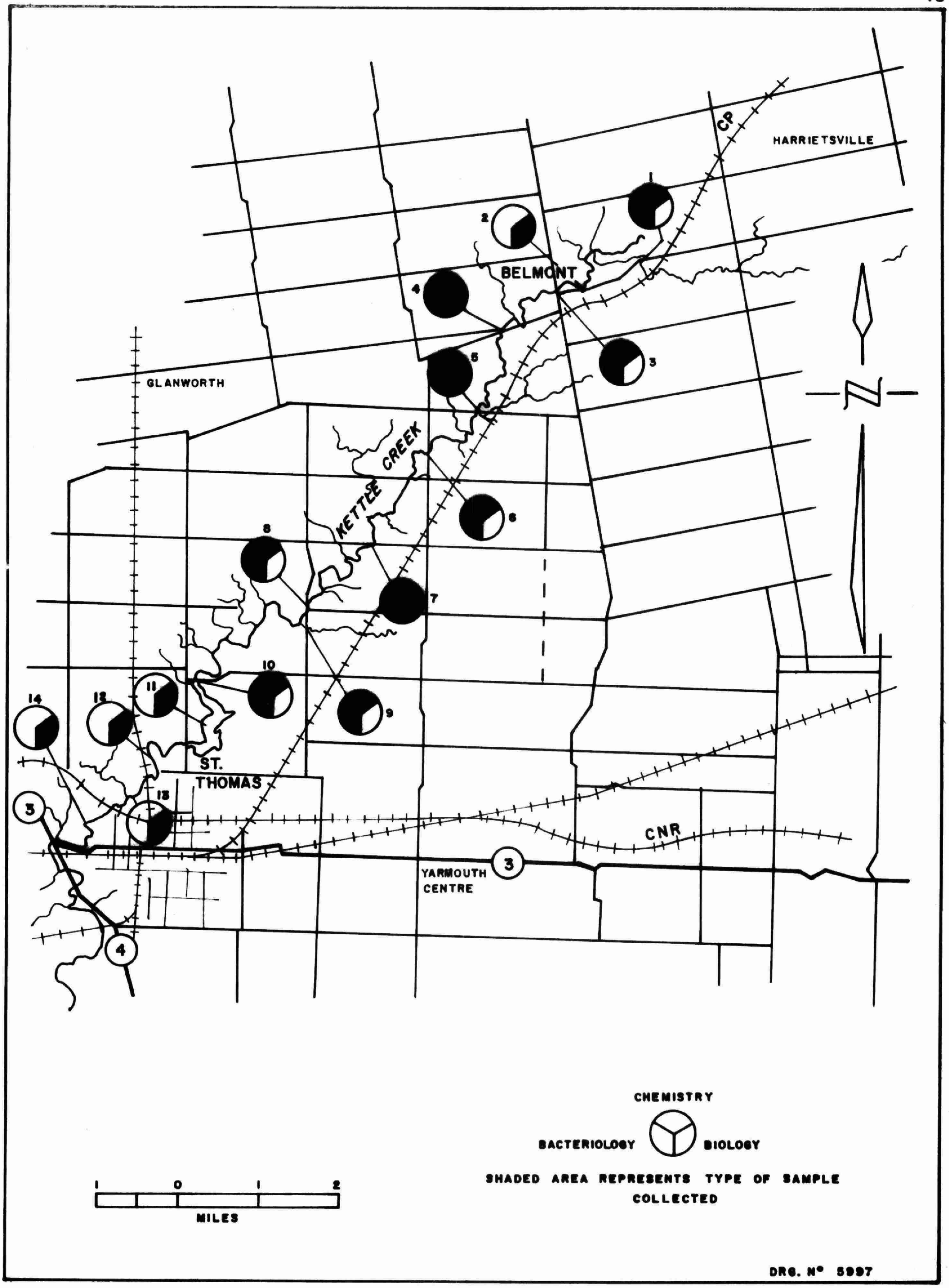

FIGURE 3 WATER QUALITY DATA POINTS ON KETTLE CREEK FROM BELMONT TO ST. THOMAS (1973).

minimum daily could be substantially lower especially during the early days in March and the last days in April. The values for November to February are 6 cfs but again the daily flows could be much less. From July to October the minimum monthly average with a 1 in 10 year recurrence is 1 cfs or less. The flow on any one day during the period could approach zero flow.

The average volume of flow passing Belmont from December through April exceeds the cumulative minimum average flow with a 1 in 10 year recurrence by a factor of 3. It is particularly important to recognize this fact in defining capabilities of the stream to dilute treated municipal wastes.

Daily mean flows in Kettle Creek during the study were relatively constant at .3 cfs for Station 1 and .9 cfs at Station 8.

Results of chemical and bacteriological analysis of water samples collected at nine stations between Belmont and St. Thomas are presented in Table 2 and dissolved oxygen and BOD results are illustrated in Figure 4. Small diurnal fluctuations in dissolved oxygen concentrations were noted at every station on upper Kettle Creek. The greatest variation occurred at Station 5 (2.6 mg/ℓ to 9.9 mg/ℓ) while the minimum fluctuation (.2 mg/ℓ to .9 mg/ℓ) occurred at Station 4. Daily mean dissolved oxygen concentrations reached the Ministry criterion of 5 mg/ℓ at all stations but Station 4 where the average level fell to .5 mg/ℓ. Night time levels from Station 3 through Station 7 violated the Ministry of the Environment guidelines

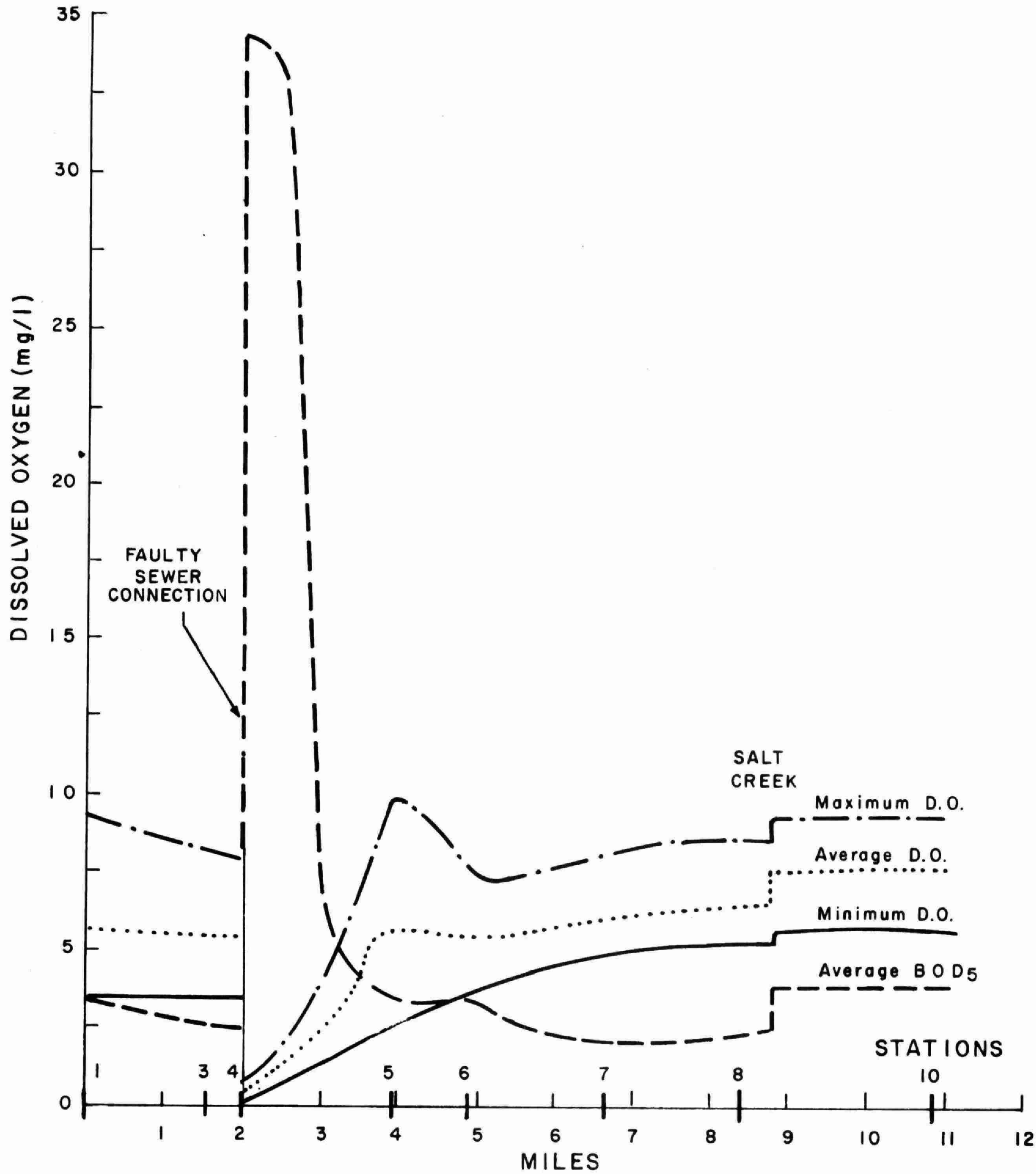

FIGURE 4: MAXIMUM, MINIMUM AND AVERAGE CONCENTRATIONS OF DISSOLVED OXYGEN AT NINE SAMPLING POINTS ON UPPER KETTLE CREEK (JULY 10, 1973)

Table 2 - Summary of water quality data collected from intensive sampling runs on Kettle Creek at 10 stations from Belmont to St. Thomas, July 10, 1973

STATION	DISS. OXYGEN mg/l MEAN	MAX.	MIN.	TEMP. °C.	BOD$_5$ mg/l MEAN	MAX.	MIN.	BACTERIA/ 100 ml GEOMETRIC MEAN TOTAL	FECAL	STREP	PHOSPHOROUS mg/l TOTAL	SOL	FREE AMM.	NITROGENS mg/l TOT. KJEL	NITRITE	NITRATE	SUSP. SOLIDS mg/l	TURBI-DITY	CHLO-RIDE mg/l
1	5.6	9.2	3.4	23.0	3.4	4.4	2.4	5,300	470	224	0.134	.012	0.04	1.1	.009	.035	35	16	22
3	5.4	8.1	3.4	22.8	2.6	2.8	2.4	23,000	538	476	0.12	.051	0.06	0.83	.020	0.11	20	10	21
4	0.5	0.9	0.2	22.2	34	55	14	49,000,000	64000	81000	1.1	0.58	0.01	2.0	.004	0.01	30	14	32
5	5.7	9.9	2.6	23.4	3.3	3.8	2.4	12,000	949	655	0.19	.061	0.03	0.87	.016	0.05	23	15	34
6	5.4	7.2	3.6	24.6	3.4	3.8	3.0	11,000	148	441	0.17	.007	0.03	1.2	.004	0.01	20	19	37
7	6.2	8.2	4.8	23.9	1.9	2.0	1.8	11,000	327	415	0.10	.008	0.02	0.74	.008	0.01	38	37	22
8	6.5	8.5	5.2	23.5	2.3	3.4	1.6	9,000	253	277	0.57	0.01	0.02	0.75	.010	0.03	55	57	19
9 (Salt Crk)	5.3	7.2	3.7	21.7	3.5	4.8	2.6	1,500	260	126	0.11	.003	0.04	1.04	.005	0.02	23	23	27
10	7.5	9.3	5.6	25.3	3.9	5.0	2.6	1,100	35	53	0.13	.021	0.07	1.2	.016	0.07	21.5	24	23

ALL RESULTS REPORTED AS ARITHMETIC MEANS UNLESS OTHERWISE STATED

Chemical and Bacteriological - 4 sample runs

D.O. and Temperature - 8 runs

for warm water biota while Stations 1, 8 and 10 exceeded this minimum criterion.

The average upstream level of BOD_5 during the survey was 3.4 mg/ℓ at reference Station 1. Average concentrations increased to 34 mg/ℓ at Station 4 below Belmont ranging from 14 mg/ℓ to 55 mg/ℓ. These high levels are thought to have been the result of accidental discharge via the cooling water discharge sewer of interior washings from bulk tank trucks at the Borden Company Limited plant. By Station 5 the mean BOD value dropped to normal levels from 3.8 to 2.4 mg/ℓ and remained in this range for the rest of the survey reach. Approximately 32 lb/day BOD was entering St. Thomas from upper Kettle Creek during the survey.

Water at reference Station 1 contained, on the average, .137 mg/ℓ total phosphorus and 1.1 mg/ℓ Kjeldahl nitrogen (TKN) with low levels of nitrate. These background levels of total phosphorus and TKN likely originated from land drainage. Below Belmont (Station 4) average concentrations of total phosphorus increased 10-fold and Kjeldahl nitrogen doubled. This was attributed to the truck washings from the Borden Company Limited plant. By Station 5, the mean levels of total phosphorus and Kjeldahl nitrogen decreased to .19 mg/ℓ and .87 mg/ℓ respectively, probably the result of uptake by aquatic vegetation and nitrification. From Station 5 downstream, mean total phosphorus and TKN levels approximated background conditions except at Station 8. During the survey, approximately 1 lb/day total phosphorus and 10.5 lb/day total nitrogen were entering St. Thomas from upper Kettle Creek.

With the exception of slight increases at Station 4, average levels of chlorides and suspended solids hovered in the 20 to 25 mg/ℓ range.

Maximum geometric mean values for selected bacteriological parameters occurred at Station 4 where total coliform, fecal coliform and fecal streptococci values were 48.6 million 63,500 and 80,500 per 100 mℓ. Minimum geometric mean values occurred at Station 10 where total coliform, fecal coliform and fecal streptococci values were 1,131, 35 and 53 counts per 100 mℓ respectively. The high bacterial levels are probably the result of Borden's accidental discharge, and natural land runoff.

Results of biological sampling are presented in Tables 1, 2 and 3 of the Appendix and illustrated in Figure 5 of the text. Upstream from Belmont at Station 2, small amounts of the alga Cladophora were widely distributed over sampling areas, and some blue-green algal growths were present. Below Belmont at Stations 4 and 5, blue-green algal scums were common in evenflow areas. Foot-long strands of Cladophora were observed growing on rocks and riffle areas, covering 100% of suitable substrate. Station 7 produced 4 foot strands of Cladophora totally covering the bottom of riffle areas.

At Station 2 upstream from Belmont, 9 species of fish including varieties intolerant of polluted conditions such as rock bass and darters were captured. Numbers of fish and diversity dropped sharply immediately below Belmont where 3 species and 35 individuals were captured. However, immediate recovery

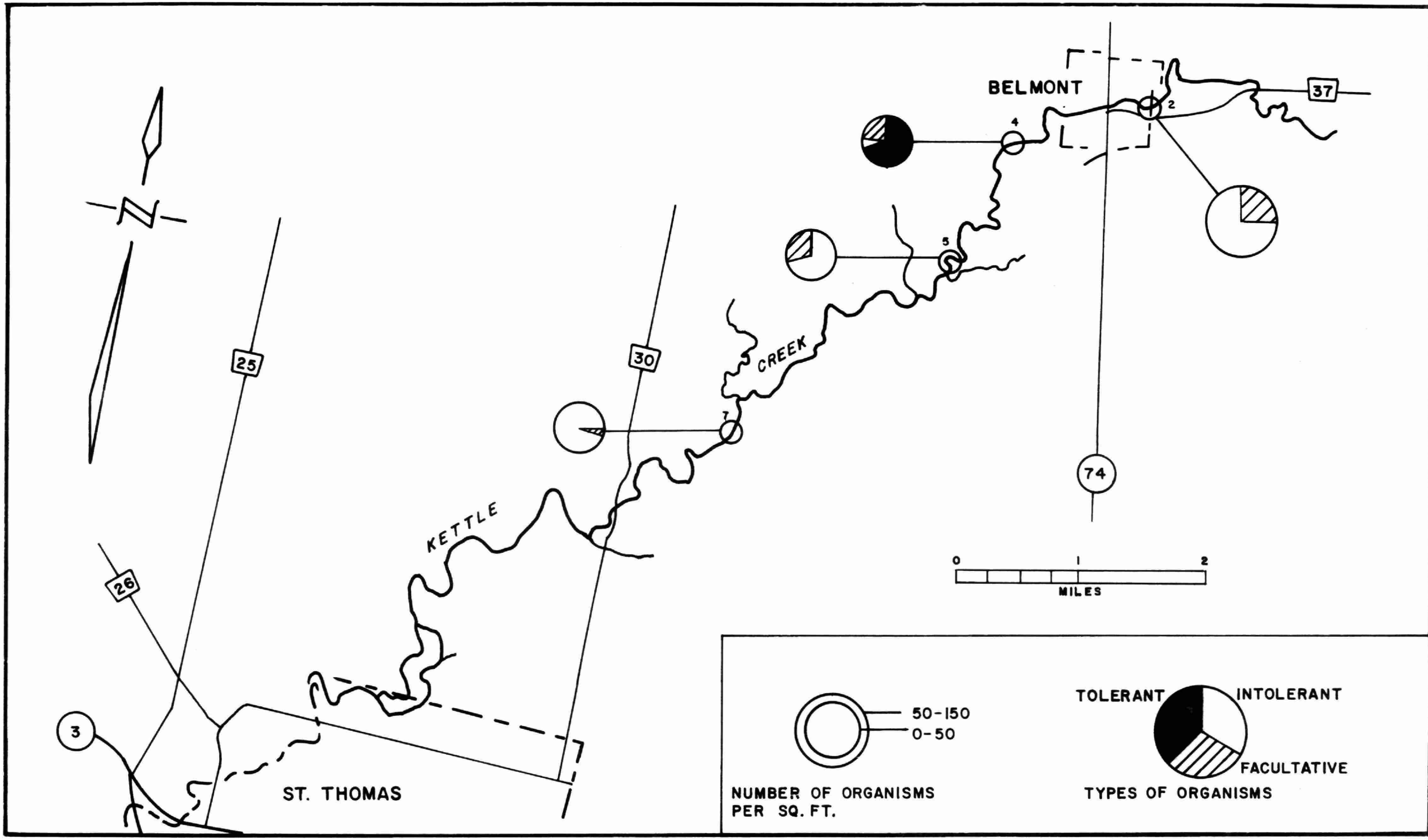

FIGURE 5 TYPES AND NUMBERS PER SQ. FOOT OF MACROINVERTEBRATES AT FOUR SAMPLING SITES ON KETTLE CREEK BETWEEN BELMONT AND ST. THOMAS — MAY, 1973.

was evident at Station 5 where 8 species including smallmouth bass and rock bass and 132 individuals were captured.

The number of different forms among the 130 aquatic invertebrates collected from a square foot area upstream from Belmont totalled 18 and intolerant forms dominated the population. At Station 4 numbers of taxa and organisms decreased to 8 and 23 respectively and pollution tolerant sludgeworms dominated the association. From this point downstream to the Waterworks Reservoir, variety among bottom fauna populations gradually increased as did the proportion of intolerant forms to other types. It would appear from the small size of populations (20 to 30 organisms per square foot) in this reach, that some natural factor(s) such as low streamflow or unfavourable substrate is limiting. In the reservoir, a silt input and depressed levels of dissolved oxygen (2 mg/ℓ) in bottom waters were the most probable causes of the virtual lack of invertebrates in bottom sediments. Only a few midges and sludgeworms were found.

Dodd Creek

Streamflows for the 8 square mile drainage area upstream from the Ford Motor Company of Canada Limited plant were pro-rated to the Dingman Creek gauge and the results are presented in Table 3 of the text. For December to April, the mean monthly flows are 10 cfs to 21 cfs with only 2 cfs or less for July to October. The lack of significant natural streamflow is further exemplified by an analysis of minimum monthly average

Table 3 - Monthly streamflow data for Dodd Creek at Highway 4.

MONTH	MEAN MONTHLY FLOWS (cfs)	MINIMUM MONTHLY AVERAGE FLOW WITH A RECURRENCE INTERVAL OF 1 IN 10 YEARS (cfs)
January	10	2
February	10	1
March	21	12
April	13	5
May	6	1
June	4	1
July	2	Ø
August	1	Ø
September	1	Ø
October	2	Ø
November	8	2
December	10	2

Note: Drainage Area : 8 square miles
Gauge : Pro-rated from 02GE005 (Dingman Creek at Lambeth)
Years of record : 1966-1974

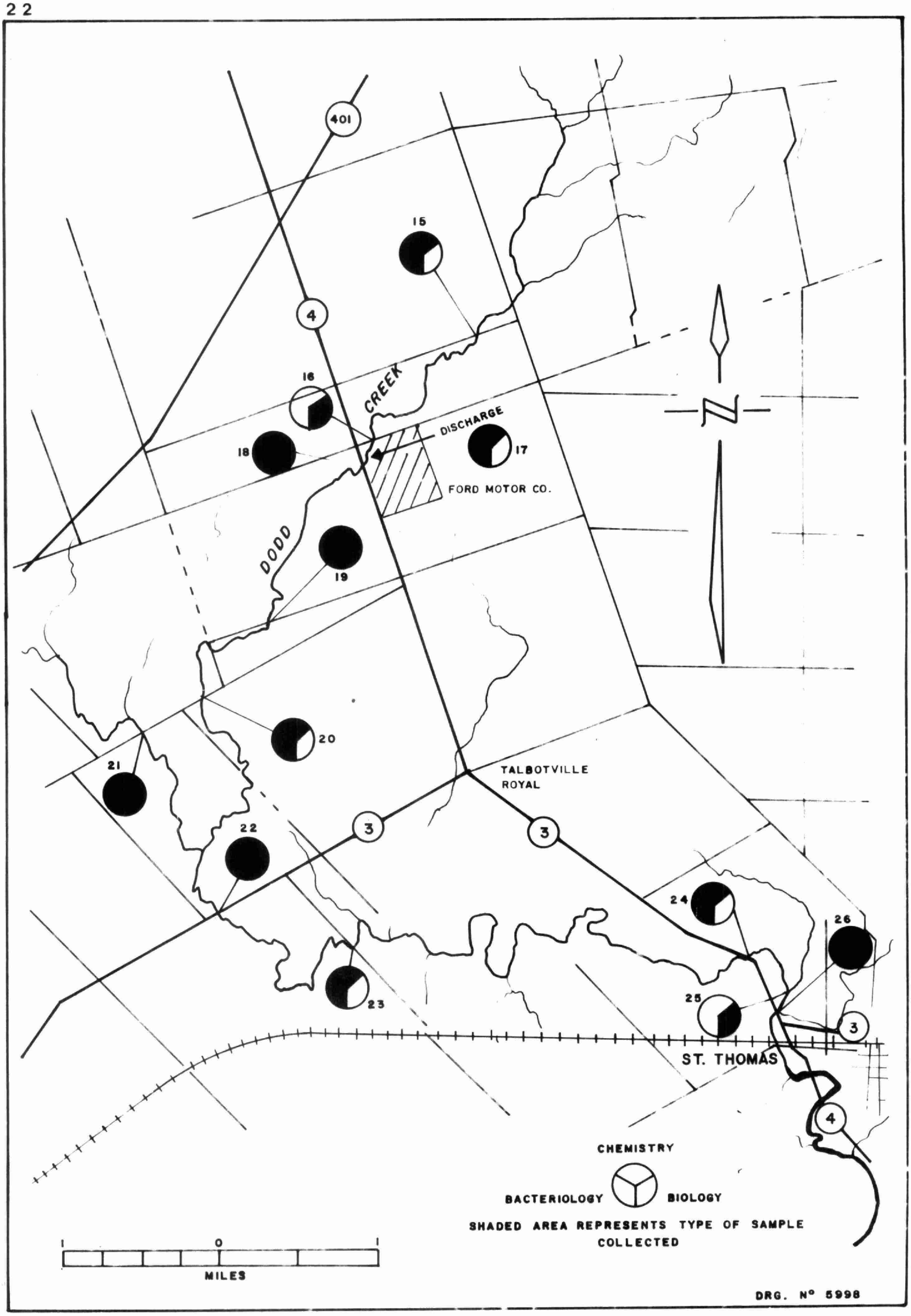

FIGURE 6 WATER QUALITY DATA POINTS ON DODD CREEK (1973).

flow with a return period of 1 in 10 years. For peak runoff periods (March) this value is only 12 cfs and from July through October the minimum monthly average one in 10 year flow is essentially zero. During the study, the measured flow immediately downstream from the Ford effluent was 2.5 cfs while the flow at the mouth of Dodd Creek was only .7 cfs. This decrease and fluctuations in streamflow noted at all sampling points on Dodd Creek are the result of sporadic discharges from the Ford Motor Company of Canada Limited lagoon.

The dampening effect on natural water temperature fluctuations by discharges from Ford was evident at all downstream stations. Average suspended solids levels were lowest at upstream reference Station 15 (11 mg/ℓ) and highest at Station 19 (110 mg/ℓ). Suspended solids concentrations in the Ford effluent varied considerably (20 mg/ℓ to 160 mg/ℓ) and these fluctuations and the variable discharge mode appeared to influence downstream concentrations. No consistent decrease in average suspended solids levels with progress downstream was evident.

An illustration of BOD and dissolved oxygen levels in Dodd Creek during the survey is presented in Figure 7. Of the 10 sites sampled only the reference Stations (15 and 21) and the final two stations on the stream (24 and 26) met minimum daily and average daily dissolved oxygen criteria. This unsatisfactory dissolved oxygen regime existed in roughly 8 to 10 miles of Dodd Creek. The Ford effluent contained on the average 2.9 mg/ℓ dissolved oxygen ranging from 2.2 mg/ℓ to 4 mg/ℓ. The gradual increase in average levels of dissolved oxygen with progress

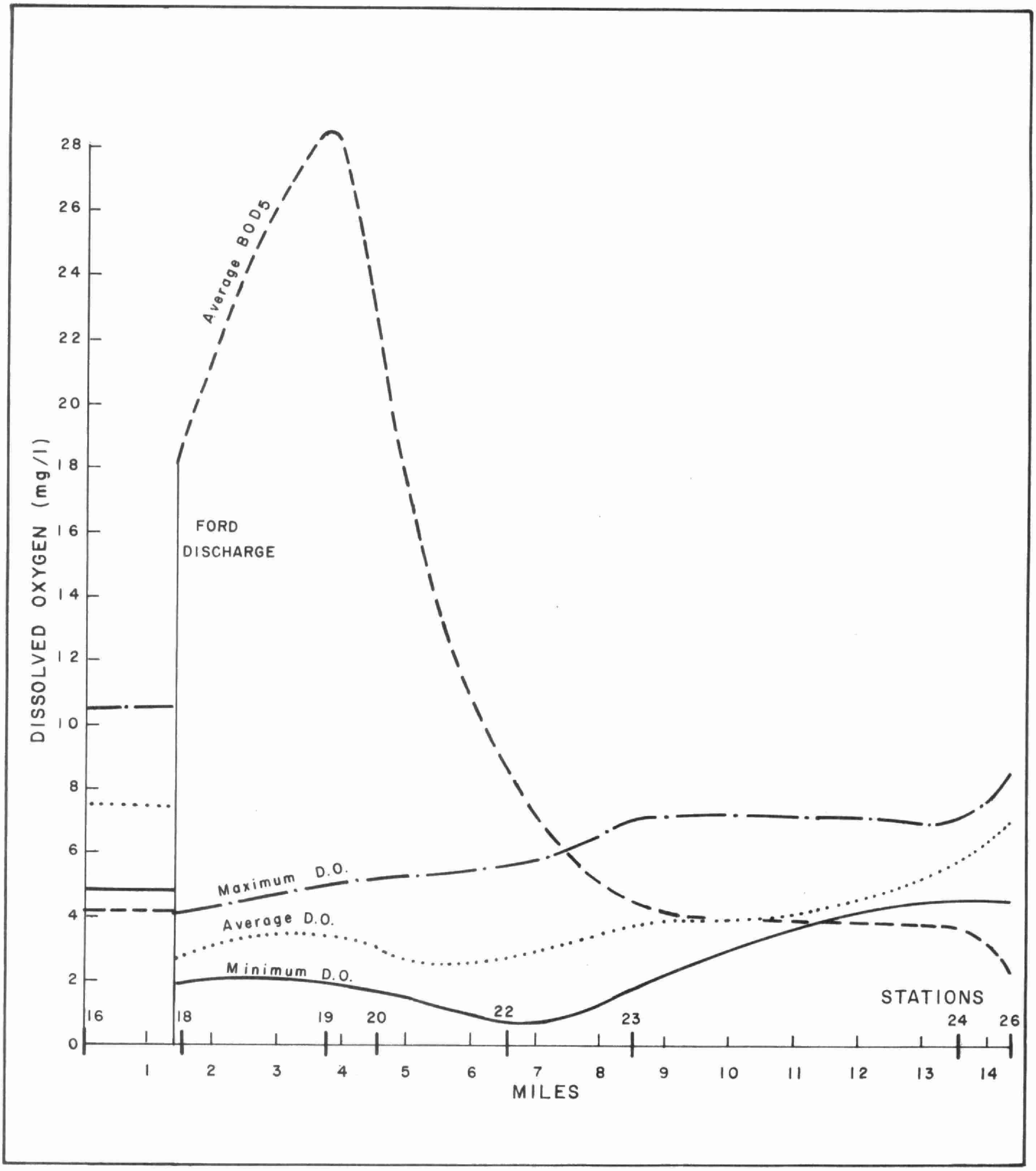

FIGURE 7 : MAXIMUM, MINIMUM AND AVERAGE CONCENTRATIONS OF DISSOLVED OXYGEN AT TEN SAMPLING POINTS ON DODD CREEK (JULY 11, 1973)

downstream to acceptable levels at the creek mouth is attributed in part to the favourable reaeration properties of the shallow stream as it falls at an average gradient of over 20 feet per mile. The maximum diurnal oxygen variation of 5.7 mg/ℓ at Station 15 reflected the small influence of photosynthesis by aquatic plants on dissolved oxygen levels.

The mean BOD_5 at reference Station 15 was 4.2 mg/ℓ varying from 3.2 mg/ℓ to 5.5 mg/ℓ. Ford's discharge (Station 17) contained a mean BOD_5 of 22 mg/ℓ ranging from 19 to 26 mg/ℓ. Approximately 100 feet downstream after mixing, the mean BOD_5 level was 18.7 mg/ℓ with a maximum and minimum of 20 mg/ℓ and 18 mg/ℓ. At Station 19 mean BOD levels increased to 28 mg/ℓ, either the result of a slug in the stream discharged before effluent sampling was initiated, delayed bacterial action or discharge of highly organic wastes from an undetermined downstream rural source. Mean BOD_5 levels dropped to 22.5 mg/ℓ by Station 20 and continued to decrease to 2.2 mg/ℓ at Station 26 at the end of the survey reach. Dodd Creek was discharging 8.8 lb/day BOD_5 into Kettle Creek during the survey.

At reference Station 15, mean levels of total phosphorus, Kjeldahl nitrogen and nitrates were .19 mg/ℓ, 1.08 mg/ℓ and .01 mg/ℓ. The Ford effluent produced on the average .62 mg/ℓ total phosphorus and 2.8 mg/ℓ TKN, a major portion of which (.75 mg/ℓ) existed in the form of free ammonia. Anaerobic conditions and the lack of profuse growth of aquatic vegetation was indicated by the persistence and the actual increase in concentrations to 2.3 mg/ℓ of nitrogen in the free ammonia form

Table 4 - Summary of water quality data collected from intensive sampling runs at 10 stations on Dodd Creek, July 11, 1973.

STATION	DISS. OXYGEN mg/l MEAN	MAX.	MIN.	TEMP. °C.	BOD_5 mg/l	BACTERIA/ 100 ml GEOMETRIC MEAN TOTAL	FECAL	STREP	PHOSPHOROUS mg/l TOTAL	SOL	FREE AMM.	NITROGENS mg/l TOT. KJEL	NITRITE	NITRATE	SUSP. SOLIDS mg/l	TURBIDITY	CHLORIDE mg/l
15	7.6	10.5	4.8	21.0	4.2	11,087	297	713	0.19	0.37	0.07	1.08	0.009	0.01	11.2	64.9	19
17 (Ford dischge)	2.9	4.0	2.2	22.2	22.0	328,133	13	11	0.62	0.27	0.75	2.8	0.048	0.07	55	64.5	51
18	2.8	4.2	1.8	21.9	18.7	134,361	26	25	0.9	0.41	0.81	3.1	0.058	0.07	25	6.9	90.7
19	3.2	4.9	2.0	21.1	28.5	327,189	4,670	1,049	0.87	0.41	1.8	3.8	0.015	0.02	110	48.5	90.5
20	3.1	5.2	1.6	20.9	22.5	325,098	2,788	493	0.81	0.50	2.3	3.9	0.035	0.02	17.5	19	87.5
21(trib)	5.5	6.2	4.9	20.3	4.9	2,979	408	348	0.14	0.06	0.13	1.9	0.005	0.01	30	21	49
22	2.7	5.5	.7	21.3	8.9	13,933	634	661	0.61	0.30	0.82	2.1	0.015	0.04	30	20	81
23	3.8	7.1	1.8	22.3	4.6	16,404	132	147	0.49	0.36	0.17	1.1	0.008	0.01	15	15.3	70
24	5.9	7.0	4.5	22.9	3.9	13,204	163	234	0.24	0.10	0.05	1.2	0.009	0.01	40	57	57
26	6.7	8.8	4.4	21.7	2.2	13,414	336	353	0.17	0.056	0.05	1.01	0.015	0.02	43	61	57

ALL RESULTS REPORTED AS ARITHMETIC MEANS UNLESS STATED OTHERWISE

Chemical and Bacteriological - 4 runs

D.O. and Temperature - 8 runs

and persistently high total phosphorus levels (.61 mg/ℓ) roughly 5 miles downstream to Station 22. It should be noted that such ammonia concentrations can be acutely toxic to fish life. Further downstream, nutrient levels gradually decreased to background conditions at the mouth of Dodd Creek (Station 26).

Chloride levels increased from a background of 19 mg/ℓ to a peak of 90 mg/ℓ at Station 18. This maximum average concentration was reduced by roughly one third by the end of the survey reach.

Dodd Creek suffers from bacteriological contamination from reference Station 15 to its confluence with Kettle Creek. The geometric mean levels are above the Ministry of the Environment criteria for livestock watering, irrigation and body contact recreation. Maximum geometric mean levels for total coliform in the creek occurred at Station 17 in the Ford discharge (328,133 per 100 mℓ) while maximum levels of fecal coliform and fecal streptococci were found at Station 19 (4,670 per 100 mℓ and 1,049 per 100 mℓ).

Biological sampling results are illustrated in Figure 8 and summarized in greater detail in Tables 1, 2 and 3 of the Appendix. In late May when biological sampling was conducted, *Cladophora* was present at all stations which afforded suitable substrate. It was particularly evident at Station 18 where 3-foot long strands were found covering most of the faster-flow areas. At Station 26 growth was profuse. *Cladophora* gave way to blue-green algae scums in silted, evenflow areas from

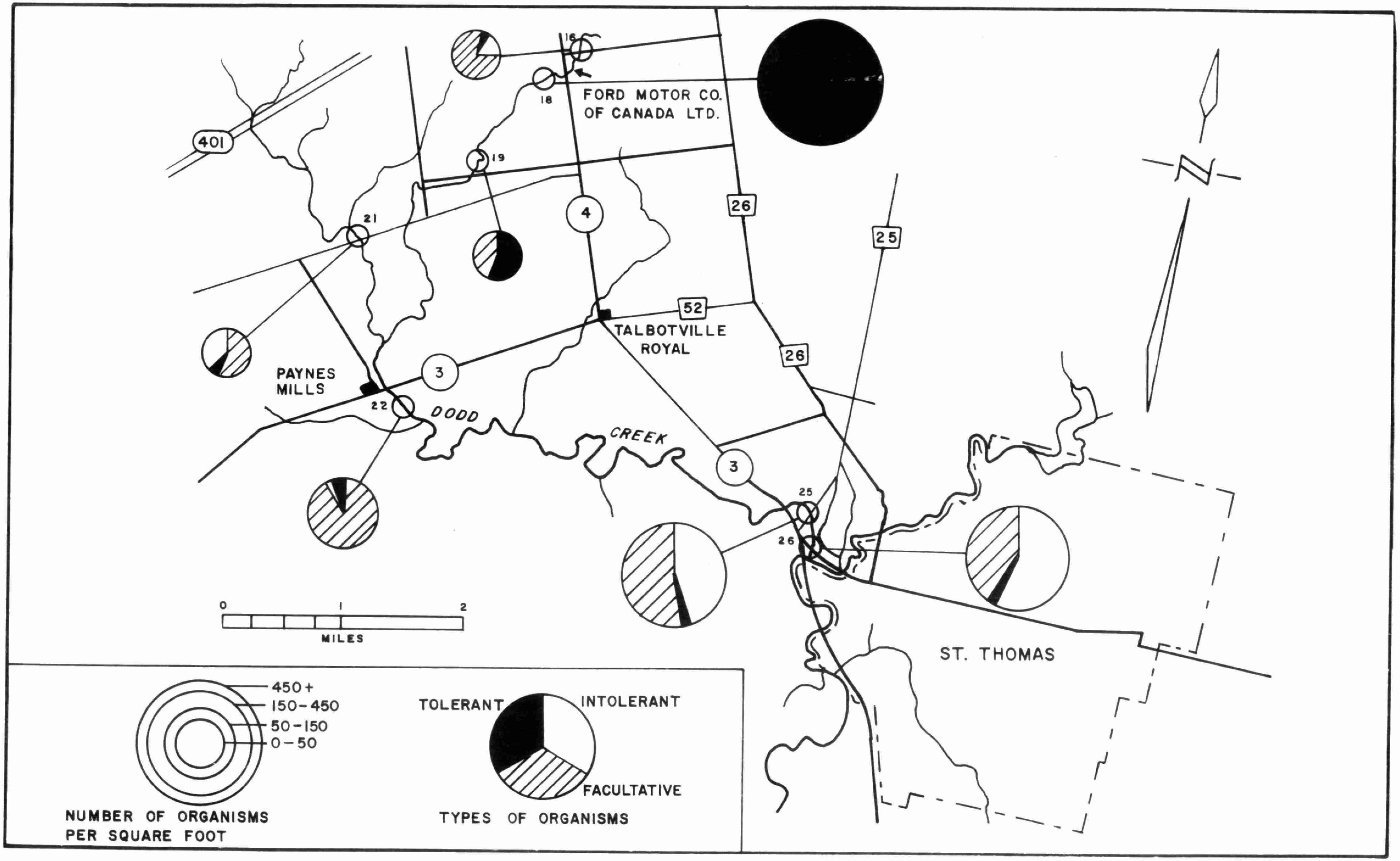

FIGURE 8 TYPES AND NUMBERS PER SQ. FOOT OF MACROINVERTEBRATES AT SEVEN SAMPLING SITES ON DODD CREEK, MAY 1973.

Station 18 where growth was heavy to Station 25. Fish populations were depressed throughout Dodd Creek as few species (a total of 11) were found and total numbers were low. Most individuals were less than 3 inches long, the result of environmental limitations in the stream. Whereas 7 species and 39 individuals including a northern pike were found at Station 16 upstream from the Ford plant, only 7 individuals, representing 3 different species were captured at Station 18 downstream from the plant. Both numbers and variety of fish remained low to the mouth of Dodd Creek.

At Stations 16 and 21 chosen to be representative of background water quality, intolerant benthic invertebrates were found to be common. Twenty percent of the population at Station 16 and forty-one percent at Station 21 was considered intolerant. Although population sizes were small, forms collected were varied - 19 different types at Station 16 and 15 taxa at Station 21. Of the 11 taxa taken at Station 18 below Ford of Canada Limited, Tubificidae (sludgeworms) comprised 99% of total individuals. Most intolerant types were rare or absent at this station. This fact plus the fact that the total number of organisms (548) was eleven times the number taken at reference Station 16 indicate organic enrichment at this station. The extremely stunted population and lack of pollution intolerant forms at Station 19 were indicative of toxic conditions. Improvement at Station 22 to 15 species and 123 individuals was likely the result of increased flows from the west branch of Dodd Creek. Intolerant forms were found in limited numbers. Intolerant stoneflies, mayflies and caddisflies dominated taxa

at Station 25 representing 47% of individuals. Good water quality was evident from this station to the junction of Dodd Creek with Kettle Creek. Station 26 just upstream of the confluence showed similar conditions with 57% of the population being intolerant although higher numbers of the caddisfly *Hydropsyche* would tend to indicate organic enrichment at this location.

Kettle Creek (St. Thomas to Port Stanley)

Results of analysis of historical streamflow records for the 127 square mile drainage basin above the St. Thomas Federal gauge are presented in Tables 5 and 6 of the text and illustrated in Figures I through IV of the Appendix. As indicated by mean monthly flows for the year (Table 5), the impermeable nature of the soils in the upper basin results in large amounts of runoff in the spring and low flows in the summer and early fall. Most of the runoff occurs from December to April when mean monthly flows exceed 140 cfs and peak runoff occurs during March and April. From July to October mean monthly flows are less than 25 cfs.

The minimum monthly average flow with a return period of 1 in 10 years is greatest for March, having a value of 100 cfs (Table 5). During the June to November period minimum monthly average flows with a return period of 1 in 10 years are usually less than 6 cfs. The flows during December to February for the minimum monthly average 1 in 10 year return period are substantially lower than the mean monthly for the same period. The

Table 5 - Monthly streamflow data for Kettle Creek at St. Thomas.

MONTH	MEAN MONTHLY FLOWS (cfs)	MINIMUM MONTHLY AVERAGE FLOW WITH A RECURRENCE INTERVAL OF 1 IN 10 YEARS (cfs)
January	177	22
February	189	12
March	297	100
April	221	42
May	89	8
June	94	5
July	23	3
August	20	3
September	11	2
October	17	4
November	116	6
December	144	18

Note: Drainage Area : 127 square miles
Gauge : 02GC002
Years of record : 1967-1974

Table 6 - Summary of flow values from a duration analysis of streamflow on Kettle Creek at St. Thomas from 1968-1973.

PERIOD OF ANALYSIS 1968-1973	PERCENTAGE OF TIME INDICATED DISCHARGE WAS EQUALLED OR EXCEEDED %	DISCHARGE cfs
January to December	99	1.5
	98	2.2
	95	3.0
	90	3.5
	80	5.7
March to April	99	10
	98	11
	95	15
	90	27
	80	50
June to October	99	1.1
	98	1.4
	95	2.3
	90	2.9
	80	3.5

discharge volume from the mean monthly flows for Kettle Creek at St. Thomas for December to April is about 5 times greater than the minimum monthly average flows with a recurrence interval of 1 in 10 years for the same months.

As indicated in Figure I, (Appendix), the probability in any year of the minimum 7-day average flow being 2.6 cfs is 50%. In other words, a minimum 7 day average flow of 2.6 cfs could be expected every second year. The minimum 7 day average flow with a recurrence interval of 1 in 10 years is only .6 cfs. To further exemplify the critical nature of streamflow at St. Thomas, frequency analysis for minimum 15 day and 30 day average flows for each year of record are portrayed in Figure II of the Appendix. It is interesting to note that every second year, minimum average flows over a 30 day interval could be expected to be roughly 5 cfs. During the intensive sampling runs, streamflow at St. Thomas was over 20 times greater than the minimum 7 day average flow with a 1 in 10 year recurrence interval. Table 6 summarizes significant results of flow duration analysis (Figure III and IV of the Appendix). For low flow periods (June to October) a discharge of 2.9 cfs was equalled or exceeded 90% of the time.

Despite the fact that the final portion of the survey was conducted under storm conditions, water temperature varied only slightly at all survey stations. The mean water temperature for this reach was 22.4°C during the survey.

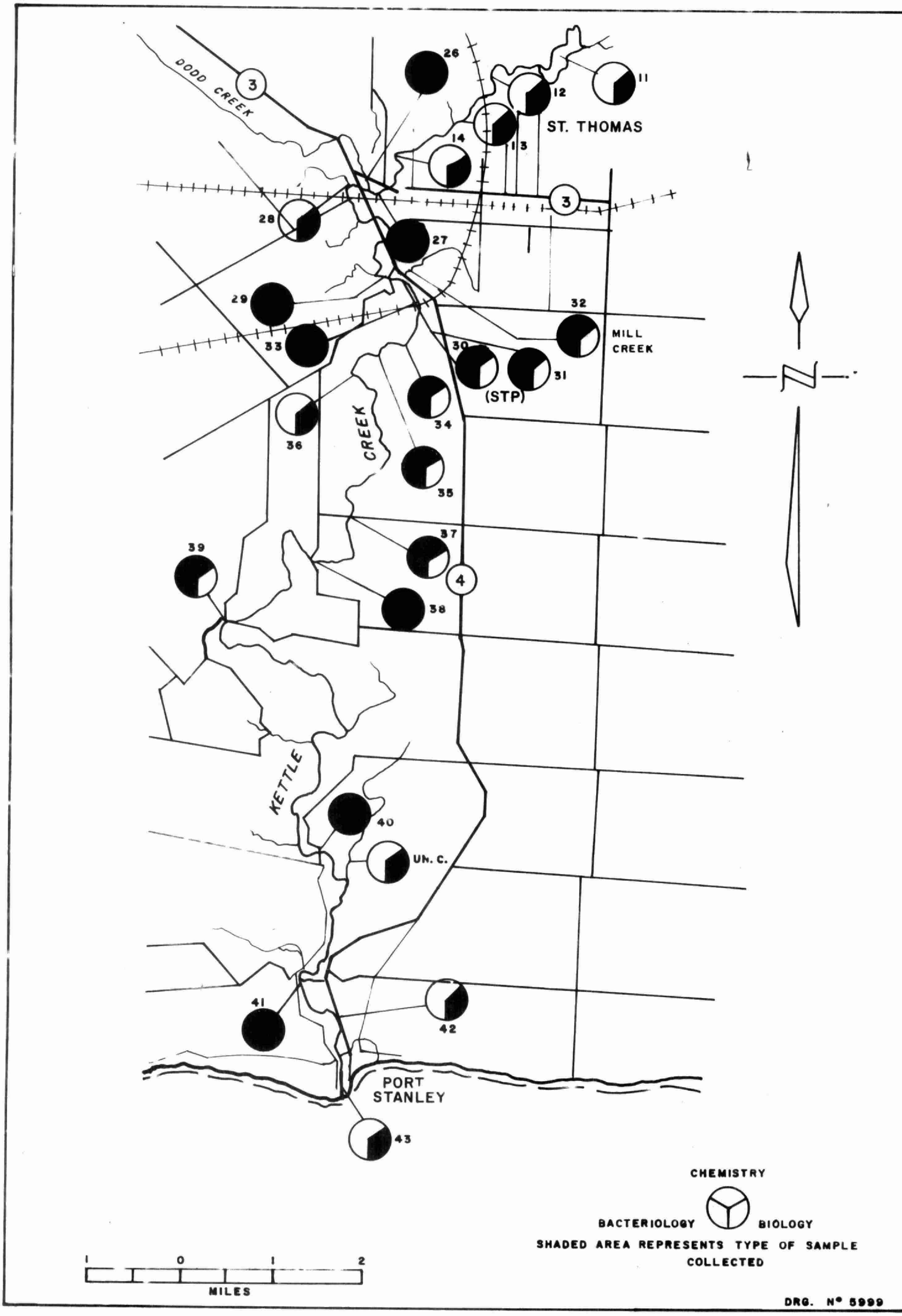

FIGURE 9 WATER QUALITY DATA POINTS ON KETTLE CREEK FROM ST. THOMAS TO PORT STANLEY (1973).

Although average daily streamflow during the survey far exceeded the expected low flow condition, mean daily levels of dissolved oxygen achieved Ministry guidelines at only 4 locations - the mouth of Dodd Creek (Station 26), the mouth of Mill Creek (Station 32), immediately downstream from Mill Creek and the sewage facilities (Station 33), and at Station 40 upstream from Port Stanley. With the exception of Mill Creek and Station 33 immediately downstream, minimum daily levels of dissolved oxygen fell below 4 mg/ℓ at all stations in the survey reach. Values at reference Stations 26, 27 and 29 were influenced by storm conditions towards the end of the sampling period which in part accounts for the lower than expected results. At Station 33 downstream from the discharges from the sewage treatment plants and Mill Creek, the mean dissolved oxygen level was 5.4 mg/ℓ ranging from 4.5 mg/ℓ to 6.7 mg/ℓ. Reaeration provided by a riffle immediately upstream from this site probably accounts for these unexpected results. From Station 34 to Station 41, little sign of dissolved oxygen improvement was evident. Mean values ranged from 4.2 mg/ℓ to 5.1 mg/ℓ and minimum levels varied from 2.6 mg/ℓ to 3.9 mg/ℓ.

High BOD_5 values prevailed throughout the total reach during the survey. Mean survey BOD_5 for Station 26 (Dodd Creek) was 5.7 mg/ℓ while Station 27 (upper Kettle Creek) had a mean of 7.5 mg/ℓ. These levels are high compared to earlier surveys due to the increased urban runoff and combined sewer overflows resulting from the rain storm. In the effluent of St. Thomas Sewage Treatment Plants 2 and 3, the mean BOD_5 was 8.6 mg/ℓ while Plant 1 produced an average BOD of 22.3 mg/ℓ ranging from

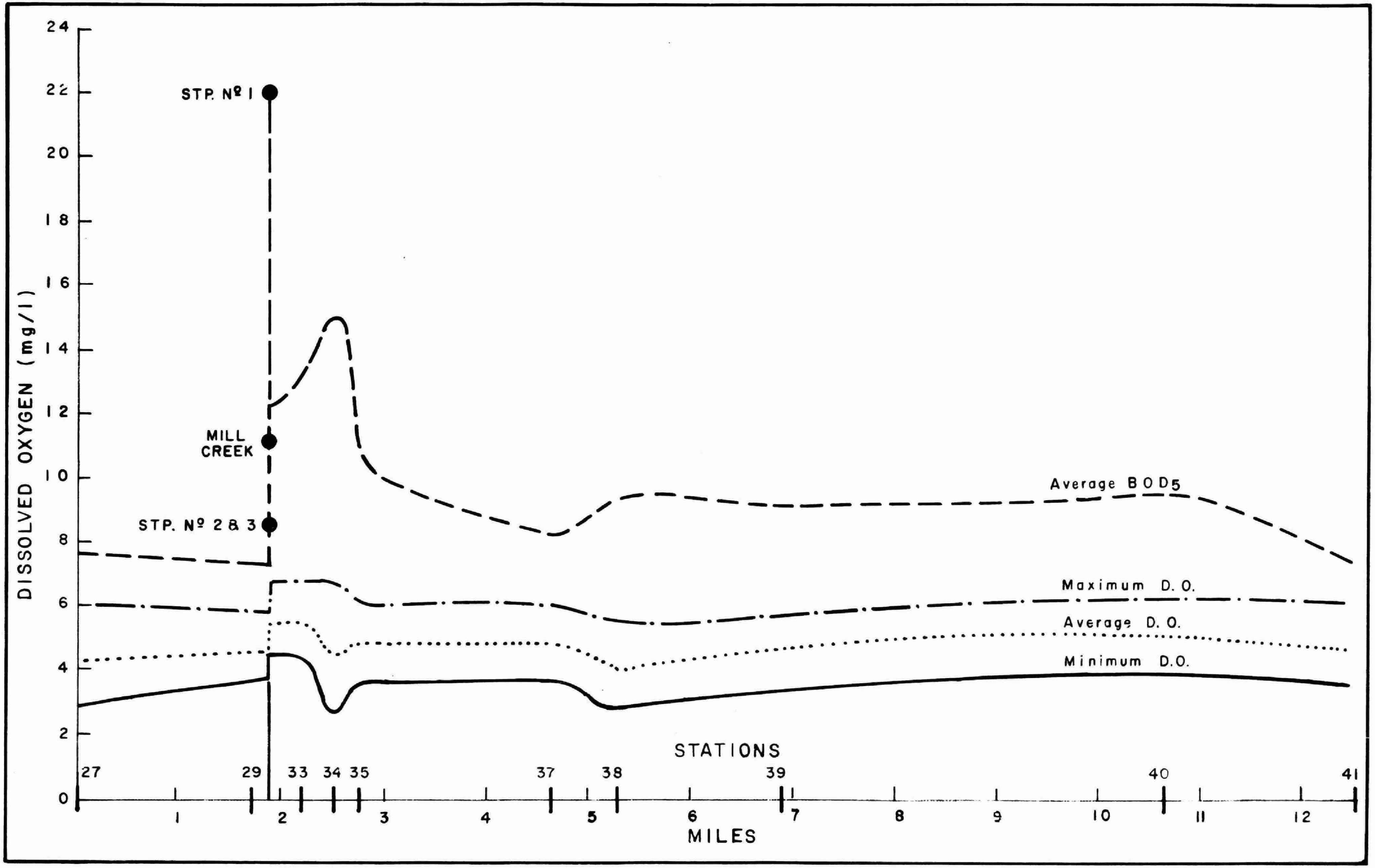

FIGURE 10: MAXIMUM, MINIMUM AND AVERAGE CONCENTRATIONS OF DISSOLVED OXYGEN AT TWELVE SAMPLING POINTS ON LOWER KETTLE CREEK (AUGUST 1 & 2, 1973)

15 to 34 mg/ℓ. Following mixing of the treatment plant effluents with Kettle Creek and inputs (11.4 mg/ℓ) from Mill Creek, the level at Station 33 was 13.1 mg/ℓ and increased to 15 mg/ℓ by Station 34. Between Stations 34 and 40, the average BOD_5 concentration varied from 10.6 mg/ℓ to 8.2 mg/ℓ. At Port Stanley (Station 41) the mean BOD_5 was 7.5 mg/ℓ.

Average levels of total phosphorus and total kjeldahl nitrogen at Stations 26, 27 and 29 were approximately .27 mg/ℓ and 1.2 mg/ℓ. Sewage Treatment Plants 2 and 3 contributed 2.1 mg/ℓ total phosphorus and 3.5 mg/ℓ kjeldahl nitrogen while Sewage Treatment Plant 1 contributed 1.9 total phosphorus and 2.12 mg/ℓ kjeldahl nitrogen. Mill Creek (Station 32) discharged .23 mg/ℓ total phosphorus and .85 mg/ℓ kjeldahl nitrogen into Kettle Creek. After mixing (Station 33), total phosphorus and kjeldahl nitrogen levels were .98 mg/ℓ and 1.9 mg/ℓ respectively. By Station 35, average total phosphorus and kjeldahl nitrogen increased to 1.1 mg/ℓ and 2.4 mg/ℓ while at Station 37, the mean levels decreased to .63 mg/ℓ and 1.3 mg/ℓ. Levels remained in this range for the rest of the downstream stations except Station 40 where a slight increase in total phosphorus and kjeldahl nitrogen was noted. Most of the nitrogen was in the nitrate form at the majority of stations.

Chloride concentrations decreased only slightly below background levels of 43 mg/ℓ with progress downstream. For the most part, average levels approximated those found in the sewage plant effluents.

Table 7 - Summary of water quality data collected from intensive sampling runs at 14 stations on Kettle Creek from St. Thomas to Port Stanley, Aug. 1-2, 1973

STATION		DISS. OXYGEN mg/l MEAN	MAX.	MIN.	TEMP. °C.	BOD_5 mg/l MEAN	MAX.	MIN.	BACTERIA/ 100 ml GEOMETRIC MEAN TOTAL	FECAL	STREP	PHOSPHOROUS mg/l TOTAL	SOL	FREE AMM.	NITROGENS mg/l TOT. KJEL	NITRITE	NITRATE	SUSP. SOLIDS mg/l	VOLATILE SUSP. SOLIDS mg/l	TURBIDITY	CHLORIDE mg/l
Dodd	26	5.4	6.6	3.5	22.9	5.7	7.0	4.8	34000	2300	880	0.27	0.08	0.11	1.3	0.013	0.18	68	16	82	71
	27	4.2	6.0	2.8	22.3	7.5	8.5	6.0	151000	20000	1475	0.27	0.13	0.31	1.2	0.081	0.53	42	13	35	42
	29	4.6	5.6	3.6	22.7	7.3	8.0	7.0	117000	13000	1262	0.24	0.10	0.19	1.1	0.051	0.44	52	11	54	44
STP	30	4.6	6.0	2.9	21.3	8.6	10.0	6.0	35000	1000	214	2.1	1.7	0.07	3.5	0.015	1.8	5	5	3	46
STP	31	3.1	5.0	1.8	20.8	22.3	34.0	15.0	3153000	36000	8533	1.9	1.7	0.89	2.12	0.54	4.2	40	33	17	37
Mill	32	6.0	7.0	4.9	22.9	11.4	28.0	6.0	43000	600	399	0.23	0.04	0.08	0.85	0.043	1.2	7.5	5	39	35
	33	5.4	6.7	4.5	22.5	13.1	24.0	8.0				0.98	0.61	0.15	1.9	0.32	2.8	257	22	96	42
	34	4.4	6.8	2.6	23.0	15.0	22.0	8.0				0.98	0.55	0.04	1.7	0.53	3.0	211	23	74	37
	35	4.8	6.0	3.7	22.8	10.6	13.0	7.5				1.1	0.55	0.07	2.4	0.23	3.9	540	28	83	38
	37	4.8	6.0	3.7	22.2	8.2	10.0	5.0	128000	20000	2948	0.63	0.29	0.20	1.3	0.11	2.0	76	36	61	37
	38	4.2	5.6	2.9	22.3	9.4	11.0	8.0	205000	13000	1437	0.66	0.28	0.27	1.4	0.13	2.0	64	28	64	34
	39	4.8	5.8	3.3	22.4	9.2	11.0	7.5	230000	23000	3136	0.64	0.28	0.29	1.3	0.14	2.2	76	16	75	30
	40	5.1	6.2	3.9	22.7	9.6	13.0	7.5	133000	13000	2139	0.86	0.50	0.56	1.7	0.14	2.4	104	24	95	37
	41	4.8	6.2	3.6	22.8	7.4	9.0	6.0	56000	6000	1740	0.68	0.31	0.31	1.3	0.12	1.8	94	22	94	38

ALL RESULTS REPORTED AS ARITHMETIC MEANS UNLESS STATED OTHERWISE

Chemical	5 sampling runs
Bacteriological	4 sampling runs
Dissolved oxygen & temp.	10 sampling runs

Maximum geometric mean bacteriological values for the Creek occurred at Station 31 (Sewage Treatment Plant No. 1) where total coliform, fecal coliform and fecal streptococci values were 3.2 million, 3,600 and 8,533 organisms per 100 mℓ respectively. Levels decreased downstream but remained well above this Ministry's guidelines for livestock watering, irrigation and body contact recreation.

Results of biological sampling on lower Kettle Creek are presented in Tables 1, 2 and 3 of the Appendix, and illustrated in Figure 11 of the text. Through St. Thomas, unsuitable substrate (hard-packed silt) and high turbidity resulted in limited algae and submerged aquatic weed production. Cladophora growths which did occur were heavily silted and unhealthy-looking. Bottom cover reached 70% at Station 29 where growths were healthier and not so silted. Substrate was more favourable for growth and flows were stronger at this point. At Station 33 downstream from the sewage facilities, Cladophora growth was sparse (20% cover) and limited in its occurrence to the west side of the stream. On the east side adjacent to the sewage works, algae growth was displaced by sewage fungus which totally covered the bottom. The entire riffle was silted and fouled by what appeared to be organic solids. Vegetative growth was virtually absent at Station 35, but at Stations 38 and 40, healthy growths of Cladophora (strands 18 inches long) covered 70% of the riffle. Blue-green scums were present in the few ponded areas along the stream bank. From Station 40 to the mouth of the Creek, occurrence of vegetation was sparse with some pond weeds in shallow shore areas and Cladophora growing on

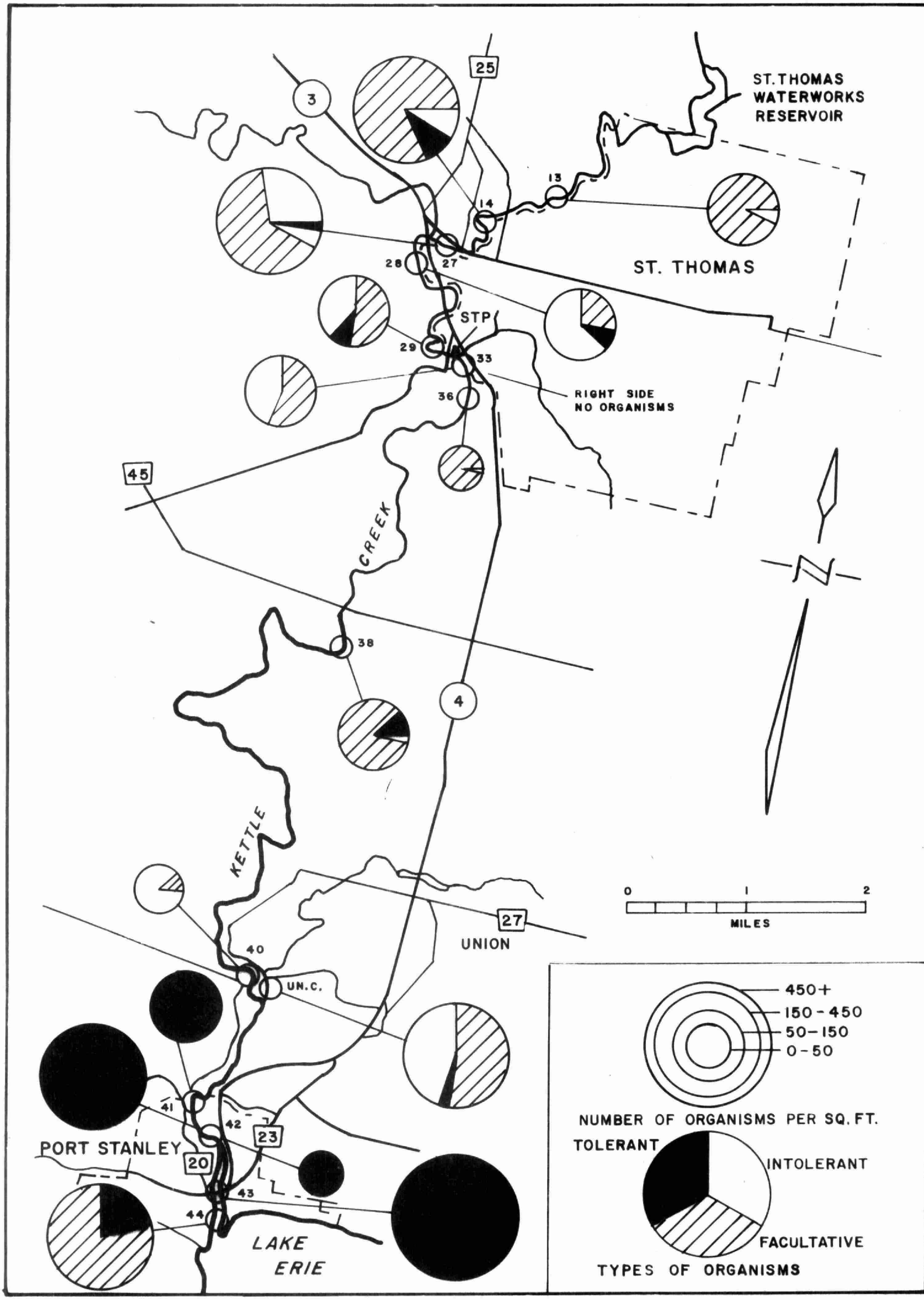

FIGURE 11 TYPES AND NUMBERS PER SQ. FOOT OF MACROINVERTEBRATES AT FOURTEEN SAMPLING SITES ON LOWER KETTLE CREEK – MAY, 1973.

suitable substrates along the shorelines, wharfs and piers. Very little plant growth was seen in Union Creek although *Cladophora* was present.

Through St. Thomas, fish populations were generally inhibited with only four (4) individuals of one species found at Station 14, while four (4) species and four individuals were recovered at Station 28. Immediately above the St. Thomas Sewage Treatment Plants, seven (7) species and 35 fish were captured including largemouth bass, black crappies and black-side darters. Variety dropped to 5 and 3 species at Station 36 and 38 respectively below the sewage treatment facilities. Twenty-five large carp were captured at Station 38. Station 40 produced 6 species and 8 individuals including channel catfish and silver bass, both lake species. Union Creek was sampled 100 yards upstream from its junction with Kettle Creek, but unfavourable physical conditions existing during the survey contributed to the limited catch (3 species and 32 individuals) at this site.

Through St. Thomas from the Waterworks Reservoir to the Dodd-Kettle Creek confluence, bottom fauna populations exhibited good variety (12 to 15 taxa) with intolerant forms represented. A dominance of blackfly larvae in the population at Station 14 accounted for a slight increase in numbers to roughly 200 per square foot. Debris and household articles discarded in the stream at this point detracted from the otherwise satisfactory water quality conditions. Based on the results of benthic invertebrate sampling, the best water quality

in the Kettle Creek watershed occurred at Stations 28 and 29 downstream from the confluence of Dodd and Kettle Creeks. Intolerant forms were common among the 20 different varieties found in the population of roughly 100 organisms per square foot. The occurrence of the stonefly Perlesta reflected the good quality of the creek upstream from the sewage facilities. At Station 33, roughly 150 yards downstream from the St. Thomas Sewage works, bottom fauna populations were severely upset. A total absence of organisms on the east side of the stream indicated conditions toxic to aquatic life. Even the most pollution tolerant sludgeworms and leeches could not be found. In contrast, the west side of the stream produced 7 taxa and 133 individuals. Two species of mayfly (Baetis and Stenonema) were collected along with the caddisfly larva Hydropsyche. Representation of these intolerant forms accounted for 44% of the organisms collected. For roughly 5 miles downstream to Station 40, intolerant forms were rare or absent even though natural physical conditions favouring such organisms (fast flow, gravel bottom) prevailed. Midge and blackfly larvae designated facultative in this study, dominated populations to Station 40, probably the result of both water quality and substrate. Some qualitative recovery was evident at Station 40 where ten taxa including one variety of mayfly and 2 caddisfly species were found in the population of 25 organisms. At a reference station at the mouth of Union Creek in this same general area, 16 different varieties were found in a population of almost 200 organisms per square foot. As a result of water depth, bottom fauna populations were sampled using a Ponar dredge in the lower evenflow section of the Creek. As expected in soft organic sediments, midge larvae

and sludgeworms dominated populations which reached roughly 1,000 organisms per square foot at Station 44. Bottom sediments were foul-smelling and emanated a sulfurous odour.

Port Stanley Harbour and Adjacent Lake Erie

Results of selected chemical and bacteriological analyses of water samples collected during three days in July 1975, from Port Stanley Harbour and adjacent Lake Erie are illustrated in Figures 12 and 13. Additional parameters determined but not reported in these Figures are available upon request from the London Office of the Ministry of the Environment.

Average levels of total phosphorus in samples collected just below the water surface ranged from 77 ppb, well within the harbour to 22 ppb at the harbour mouth. Concentrations at all stations outside the harbour in Lake Erie ranged between 10 and 17 ppb.

Levels of TKN decreased with progress through the harbour from .541 mg/ℓ at the uppermost station to .303 mg/ℓ at the harbour mouth. Outside the harbour, concentrations ranged from .243 mg/ℓ to .296 mg/ℓ. Conductivity also decreased with progress through the harbour.

A study of sediment quality in Port Stanley Harbour by Public Works Canada in 1974 recommended land disposal of the nutrient-rich spoils and the removal of "nutrients and other contaminants" from wastewaters entering Kettle Creek.

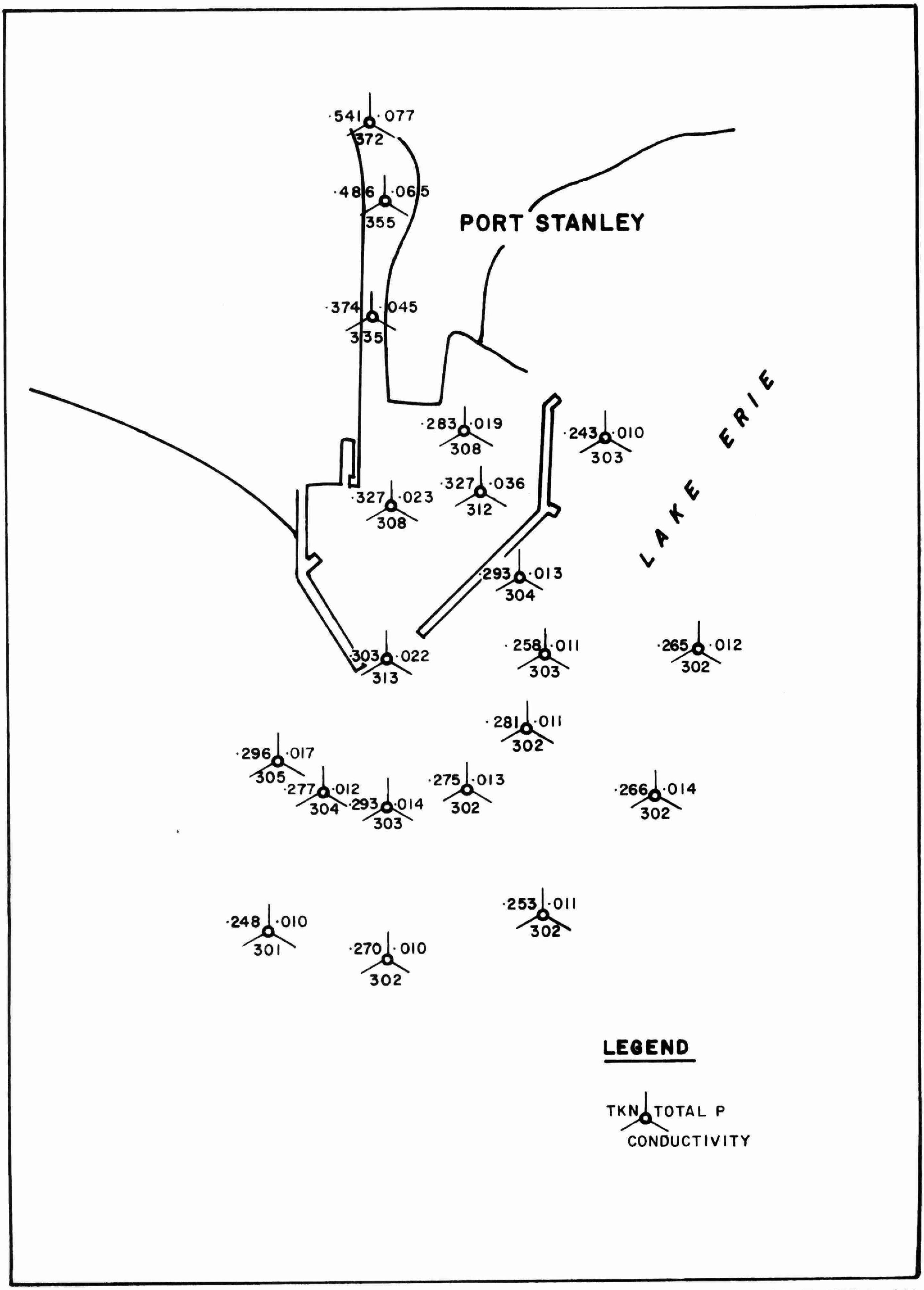

FIGURE 12: CONCENTRATIONS OF SELECTED CHEMICAL PARAMETERS IN SURFACE WATER COLLECTED FROM 20 STATIONS IN PORT STANLEY HARBOUR AND ADJACENT LAKE ERIE JULY 26, 30, 31, 1975

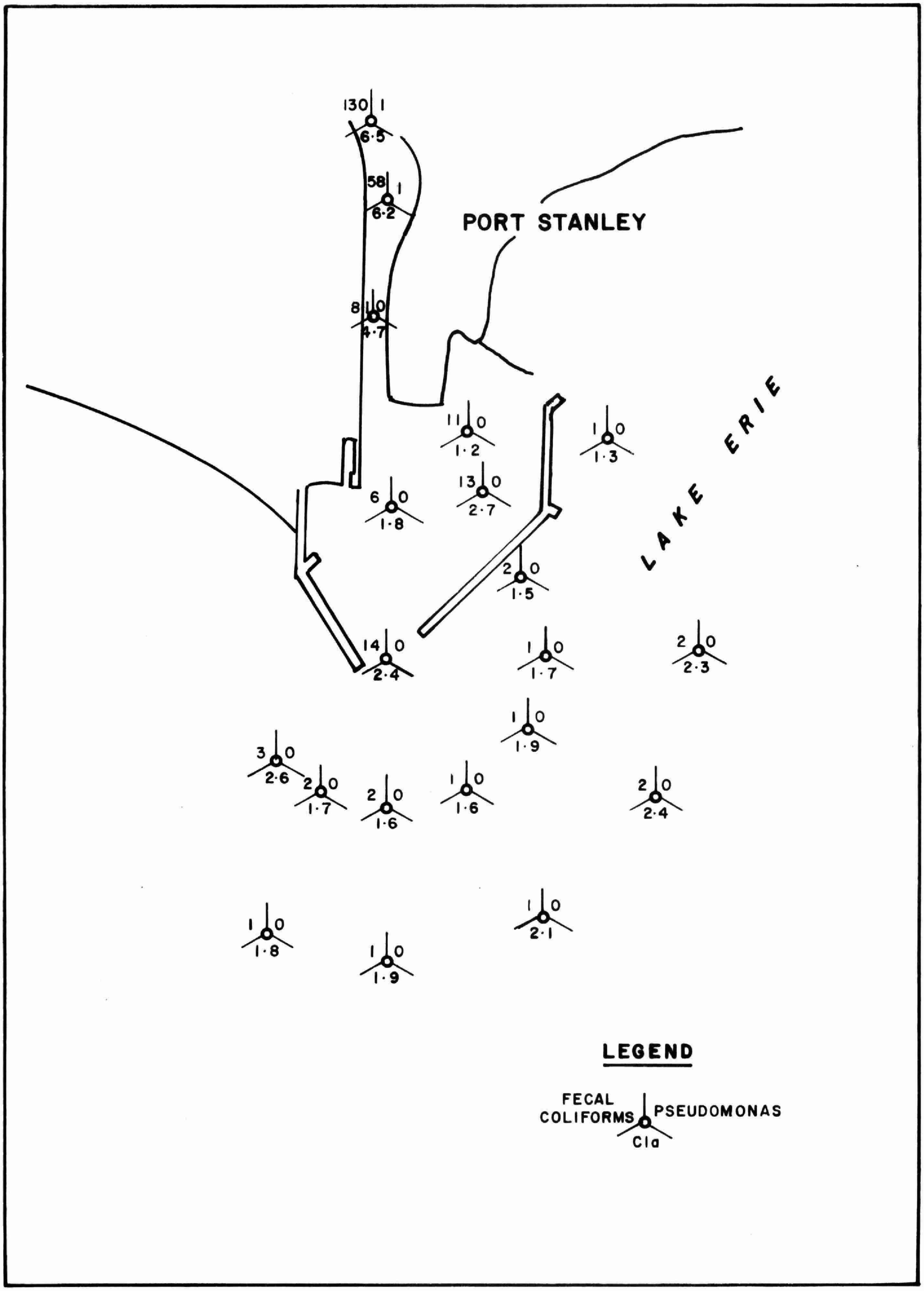

FIGURE 13: CONCENTRATIONS OF SELECTED BIOLOGICAL PARAMETERS IN SURFACE WATER COLLECTED FROM 20 STATIONS IN PORT STANLEY HARBOUR AND ADJACENT LAKE ERIE JULY 26, 30, 31, 1975

Bacteriological parameters decreased to insignificant levels outside the harbour mouth. The pathogen <u>Pseudomonas aeruginosa</u> was found only at the two innermost stations of the harbour. Geometric mean values of fecal coliforms were highest at the innermost harbour station (130/100 mℓ) and decreased to 14/100 mℓ at the harbour mouth.

DISCUSSION

General

In the Belmont to St. Thomas reach, mean daily oxygen levels met Ministry criteria at all stations but Station 4 although guidelines for minimum levels were achieved only at Stations 8 and 10. Bottom fauna and fish populations were diverse and well balanced where mean daily levels of dissolved oxygen were satisfactory. A major decrease in dissolved oxygen levels and significant increases in concentrations of most other chemical parameters at Station 4 corresponded to a drastic reduction in fish populations and a major shift in dominant bottom fauna types from intolerant to tolerant. Bacterial parameters also peaked at this station. Interference with aquatic life was short-lived as sports fish and intolerant benthic invertebrates were common 1¼ miles downstream at Station 5 and water chemistry returned to background quality at Station 7. Problems at the Borden Company Limited plant have been rectified and water quality has since improved. Low streamflows encountered during the survey (<1 cfs) are considered normal and are probably responsible for the consistently small bottom fauna populations.

In the Dodd Creek watershed, bottom fauna associations were varied and dominated by intolerant forms at the four stations where mean daily levels of dissolved oxygen achieved Ministry guidelines. From the Ford Company of Canada Limited plant to roughly 2 miles downstream from Paynes Mills, dissolved oxygen levels averaged <4 mg/ℓ, free ammonia levels appeared high and benthic invertebrate and fish populations were disrupted. Not until the last mile of stream did bottom fauna populations totally recover to background conditions and dissolved oxygen levels return to acceptable levels. Streamflow in the creek during the low flow periods is often a function of the rate of discharge from the Ford plant.

Through St. Thomas to Port Stanley water chemistry data collected during August 1973 may not have been as representative as desired owing to the effects of a storm which occurred during the sampling run. Water quality upstream from the sewage works was poorer than that found earlier in the year because of storm water and combined sewer inputs and somewhat better downstream as a result of improved streamflow to sewage ratios. During the survey, average daily streamflow exceeded average daily sewage flows by a factor of 7 while during the summer the streamflow to sewage ratio usually fell within the 2-3:1 range dropping to less than 1:1 during some weeks in September. Nonetheless, dissolved oxygen levels were critical or low as far downstream as Port Stanley during the survey. Longer term water quality as indicated by bottom-dwelling invertebrate populations appeared satisfactory through St. Thomas to the junction with Dodd Creek. The best quality in the

watershed occurred between the confluence of the two streams and the St. Thomas sewage facilities. Diversified fish populations which included largemouth bass and pollution intolerant darters were found in this reach. From the sewage facilities to Station 40 roughly 8 miles downstream, toxic conditions were indicated by the complete absence of benthic organisms or the presence of only small populations of facultative species where natural physical conditions (streamflow, substrate) were ideal for pollution intolerant forms. Limited fish populations consisted mainly of carp and suckers. A sampling site at the mouth of Union Creek provided a good comparison of numbers and variety of bottom fauna forms to be expected at nearby Station 40 on Kettle Creek. Although intolerant forms were found at Station 40, the population of 25 organisms per square foot was stunted compared to the 200 organisms collected at Union Creek. Soap detected by odour in the water and the slippery and smooth nature of the substrate may have made the development of a stable benthic population difficult in Kettle Creek at this point. Total nutrient levels did not achieve background concentrations as far downstream as Port Stanley.

In summary, it would appear that water quality is significantly impaired on each part of the watershed receiving a continuous discharge of treated municipal or industrial wastes. Dissolved oxygen levels are depressed to critical concentrations for most of Dodd Creek below the Ford plant and most of Kettle Creek below St. Thomas. Water quality degradation and interference with aquatic life are the result of organic

discharges to a watershed with low summer streamflow and hence limited year-round waste assimilation capabilities.

Objectives

Prior to the development of waste treatment guidelines for municipalities and industries in the watershed, water quality objectives must be defined. One of the fundamental objectives of the Ministry of the Environment in its water resource management role is to ensure that surface water quality is adequate to protect recognized uses and that efforts are directed towards the continual upgrading of water quality. Water uses often conflict; standards set to protect the viable trout fishery or an important swimming area may be established at the expense of use of the same water for waste assimilation purposes. By the same token, standards established strictly for the purpose of assimilation of treated wastes fall far short of providing water of a quality which is suitable for recreation, aquatic life or the watering of livestock.

This Ministry applies guidelines to protect aquatic life not only for the stated purpose but also for the associated benefits that achievement of this objective brings about. For example, the attainment of dissolved oxygen levels required by aquatic life reduces the possibility of the development of septic, malodorous sections of stream. The degree of waste treatment required to reduce organic inputs to receiving streams in the interests of aquatic life, in most cases, results in more effective waste disinfection.

Dissolved oxygen requirements by aquatic life vary with the sensitivity of the target organism and the importance of a specific stream stretch to the life history of the organism. Trout require higher levels of dissolved oxygen than do warm water species and spawning areas are more demanding in their dissolved oxygen requirements than are resting areas inhabited by adult fish.

At present, most of Dodd Creek downstream from Ford Motor Company of Canada Limited and most of Kettle Creek downstream from St. Thomas is being used almost exclusively for waste assimilation purposes. According to Ministry guidelines (Guidelines and Criteria for Water Quality Management in Ontario) creek water is unsuitable for livestock watering, irrigation and body contact recreation and from these same guidelines and data collected during 1973, aquatic life is seriously disrupted in these reaches. It is not advocated that Kettle Creek be used for swimming, owing to the lack of physically suitable areas and the proximity of other, more attractive swimming sites along the Lake Erie shoreline. However, it is recognized that cattle use both Dodd and Kettle Creeks for drinking water and efforts should be directed at improving bacteriological quality.

Suitability of the water for aquatic life must be improved and perhaps the most difficult guideline to achieve on the Kettle Creek watershed will be the dissolved oxygen criterion chosen to protect warm water species. It is this Ministry's contention that Kettle Creek presently supports a negligible sports fishery and plays a relatively insignificant

role in the propogation of anadromous commercial species from Lake Erie. By establishing a reasonable dissolved oxygen guideline, environmental conditions will improve and the strength of the fishery will be upgraded, not to its ultimate potential, but well beyond its present level. To achieve this end, it is proposed that dissolved oxygen concentrations should be above 5 mg/ℓ most of the time with allowable excursions as low as 4 mg/ℓ for short periods in any one day. Attainment of this guideline will also serve to reduce the downstream extent of the zone of effect and improve water quality conditions in downstream reaches.

Dilution ratios are critical in Kettle Creek and a statement on Ministry policy regarding this point is in order. As dilution ratios are lowered, waste water components occurring in low concentrations assume greater significance and such parameters as chloramines, phenols and ammonia can be toxic if inadequately diluted. Generally, conventional treatment may be acceptable where dilution ratios fall as low as 1.5:1. As the ratio of streamflow to treated sewage falls below this point to as low as 1:1, tertiary treatment is required. When treated waste flows threaten to exceed streamflow, either flow augmentation, waste diversion or a freeze on future development are the only alternatives available.

Although all of these criteria may be met through a properly designed and managed waste treatment system, such events as plant upsets and the discovery of new contaminants cannot be anticipated. To somewhat offset the effects of such

eventualities, and to compensate for limitations of waste water management theory and practice a certain reserve capacity is often assigned to the stream.

Keeping these objectives and water management policies in mind, waste treatment requirements for Belmont, Ford Motor Company of Canada Limited, St. Thomas and Port Stanley were developed.

WASTE TREATMENT REQUIREMENTS

Village of Belmont

When initially conceived, the discharge mode of the sewage lagoons at Belmont was to be seasonal (spring and fall) with provision of total retention during the low flow period from May through October. A closer review of monthly streamflow data (Table 1) indicated that in fact inadequate flow was available to dilute lagoon contents discharged in the fall.

To achieve acceptable concentrations of BOD and safeguard levels of dissolved oxygen in upper Kettle Creek, approximately 20 cfs streamflow is required over 20 days to safely discharge six month's storage. On a continuous discharge basis, 3 cfs is required. Streamflow requirements to empty the lagoons are met only during March and April while continuous discharge appears acceptable from November through April.

It is therefore recommended that sewage flows generated from Belmont be totally retained from May through October inclusive and that a continuous discharge equalling the daily sewage flow occur from November to April inclusive. Over a 20-day period in March to mid-April, the lagoons could be emptied to provide storage for the succeeding six month interval.

Ford Motor Company of Canada Limited

This survey has documented that many water quality guidelines are seriously violated downstream from the Ford Motor Company of Canada Limited plant as a result of a continuous discharge which frequently represents the entire streamflow in Dodd Creek during summer drought conditions. Waste treatment improvements are required to protect downstream users.

A review of streamflow characteristics for the small 8 square mile drainage basin at Ford (Table 3) indicated that for the six months from May to October, virtually no natural streamflow occurs. During this period, either the total retention and spray irrigation of treated wastes (.7 Mgd), the storage of treated wastes and subsequent discharge when streamflow is available for dilution purposes, or finally the provision of flow augmentation to allow the continuous discharge of a highly treated waste will be necessary. Failing any of these alternatives, treated wastes should be conveyed outside the watershed to a more suitable receiver.

Assuming a high level of organic reduction (BOD to 5 mg/ℓ, improved oxidation of organic nitrogen), the discharge of the .7 Mgd wasteflow could occur from November to April. Spray irrigation could take place for four months from June through September inclusive necessitating the land application of five months sewage flow. Along with an approximate 30 acres of lagoon required for storage of discharge for the month of May, it has been calculated that about 400 acres of land would be needed to avoid a net build-up of irrigated wastes in the water table.

Continuous discharge of highly treated wastes from November through April and six-month retention from May through October for subsequent discharge under more satisfactory streamflows would involve 93 acres of lagoons. This alternative is unacceptable because the drainage basin is too small to generate enough runoff in the spring to adequately dilute the large volume of stored wastes.

The provision of low flow augmentation of highly treated wastes during periods when sewage flow exceeds natural streamflow (roughly five months) is not possible by conventional means. Construction of an impoundment to store runoff from the eight square mile drainage area for later release during summer low flow conditions is impractical. However, it may be possible to obtain sufficient dilution water from the Elgin Area Water System or from inactive wells in the White Oaks well field at the headwaters of Dodd Creek when streamflows drop below sewage discharge rates. Streamflow continuously monitored upstream

from the plant could be telemetered to the sewage works and augmentation at a rate to ensure a 1:1 dilution ratio could be affected by feeding water to Dodd Creek from the Ford plant artery of the East Elgin system or from the existing White Oaks wells which are capable of providing the necessary flow. Agreement would have to be reached with the City of London before this latter source could be utilized.

All of these alternatives, only the last one of which appears worthy of consideration, involve the upgrading of treatment of the .7 Mgd waste flow to include tertiary treatment to reduce BOD concentrations to 5 mg/ℓ, nitrification and phosphorus removal to 1 mg/ℓ.

A pipeline to Lake Erie is the best solution to water quality problems created by wastes from the Ford assembly plant in Dodd Creek. Should the City of London opt for a pipeline to Lake Erie to serve future municipal waste disposal requirements (Water Management Study, Thames River Basin, 1975), connection to this pipeline should be seriously considered by the Ford (Talbotville) plant.

City of St. Thomas

Waste assimilation modelling exercises based on various streamflow conditions and loading rates indicate that dissolved oxygen criteria can be met in Kettle Creek only under continuous discharge of tertiary treated wastes. Figures 12, 13 and 14 illustrate expected dissolved oxygen concentrations with

time of travel downstream from the St. Thomas facilities at four streamflow conditions. Each figure represents a certain level of treatment of organic wastes as represented by the effluent concentration of BOD_5; 15 mg/ℓ BOD_5 (present design situation), 10 mg/ℓ BOD_5 and 5 mg/ℓ BOD_5 (effluent filtration). In each case the following assumptions were applied to the calibrated model:

1. Combined discharge from facilities - 4.5 Mgd (8.4 cfs).

2. Upstream BOD concentration (assumed following sewer separation) - 2.5 mg/ℓ.

3. Upstream dissolved oxygen concentration (measured during low flow conditions in 1966) - 6.5 mg/ℓ.

4. Sewage treatment plant effluent dissolved oxygen concentration (measured) - 4.1 mg/ℓ.

As is readily observed from Figure 14, even under a minimum streamflow of 12.6 cfs, a minimum level of dissolved oxygen of 4 mg/ℓ would not be attained until roughly 1.75 days of travel downstream (virtually the entire stream) under current design. It should be appreciated that a background flow of 12.6 cfs represents a 1.5:1 dilution ratio and that this flow would be attained only one third of the time from June to October. At the same level of treatment for streamflows of .6 cfs and 3 cfs anaerobic conditions would be expected in roughly 2 to 3 miles of the stream. From June to October, daily flows would not be

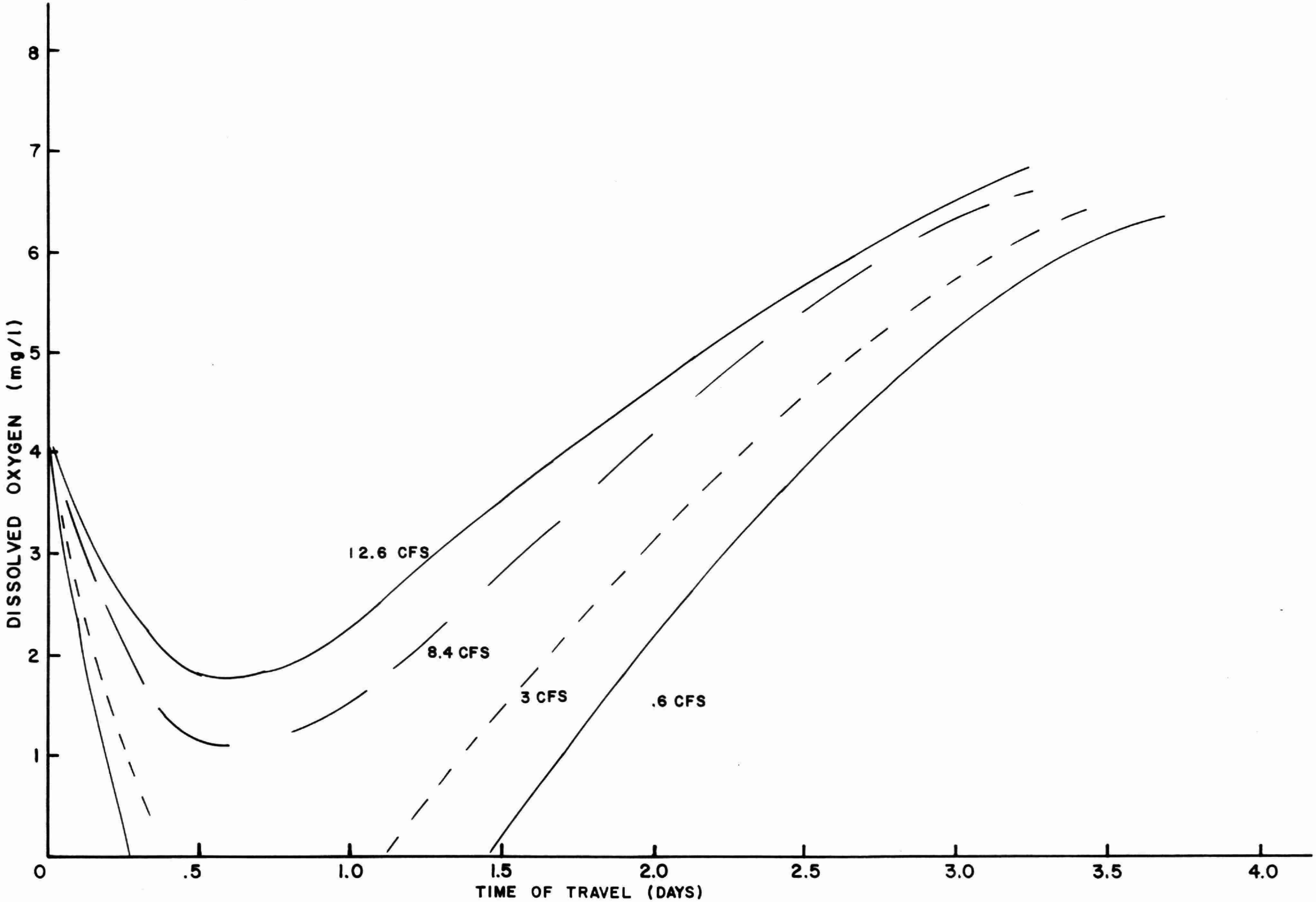

FIGURE 14 MINIMUM DISSOLVED OXYGEN LEVELS (mg/l) EXPECTED IN KETTLE CREEK UNDER FOUR STREAMFLOW REGIMES WITH EXISTING SECONDARY TREATMENT AT ST. THOMAS.

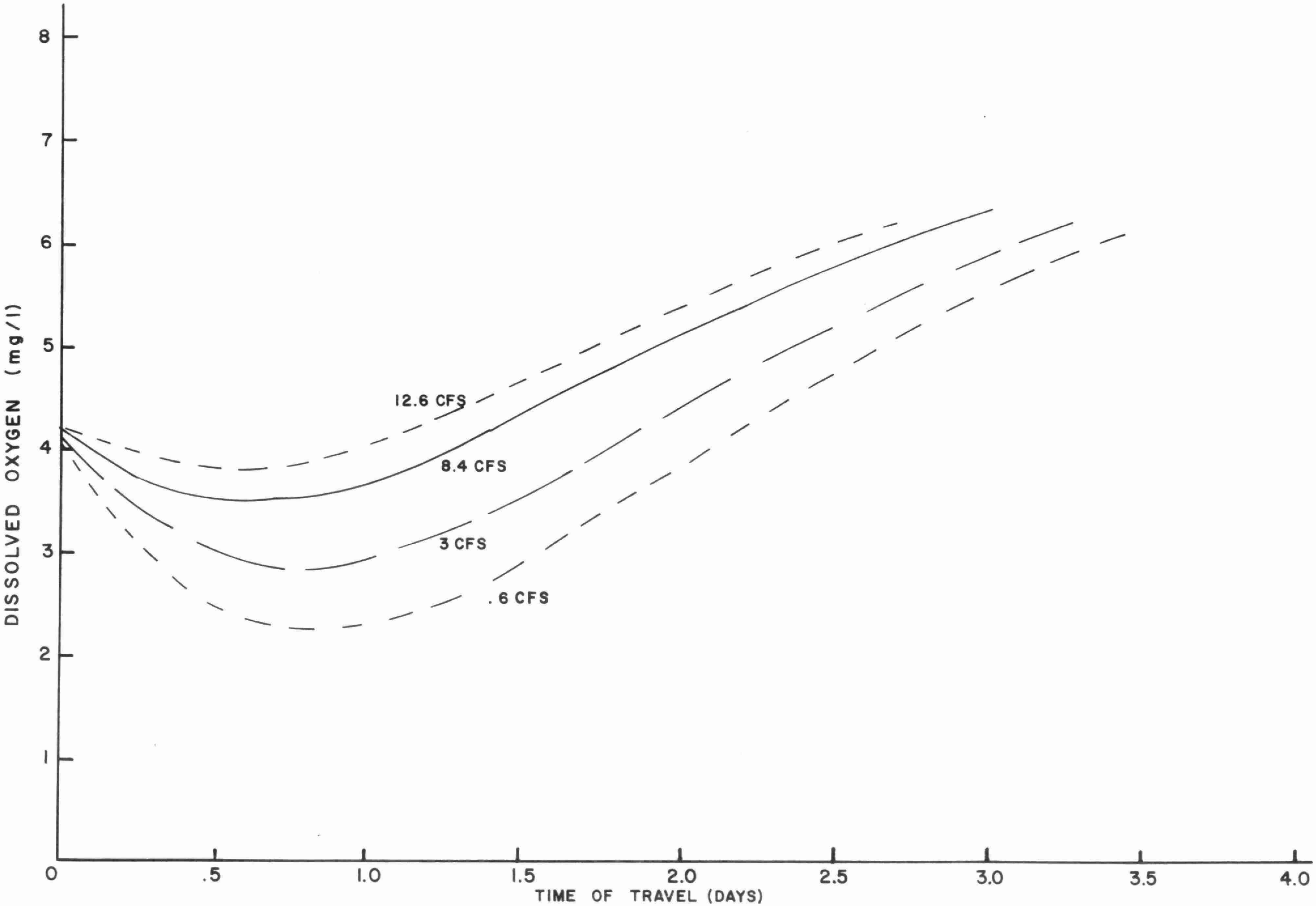

FIGURE 15 MINIMUM DISSOLVED OXYGEN LEVELS (mg/l) EXPECTED IN KETTLE CREEK UNDER FOUR STREAMFLOW REGIMES WITH TREATMENT TO 10mg/l BOD_5 AT ST. THOMAS.

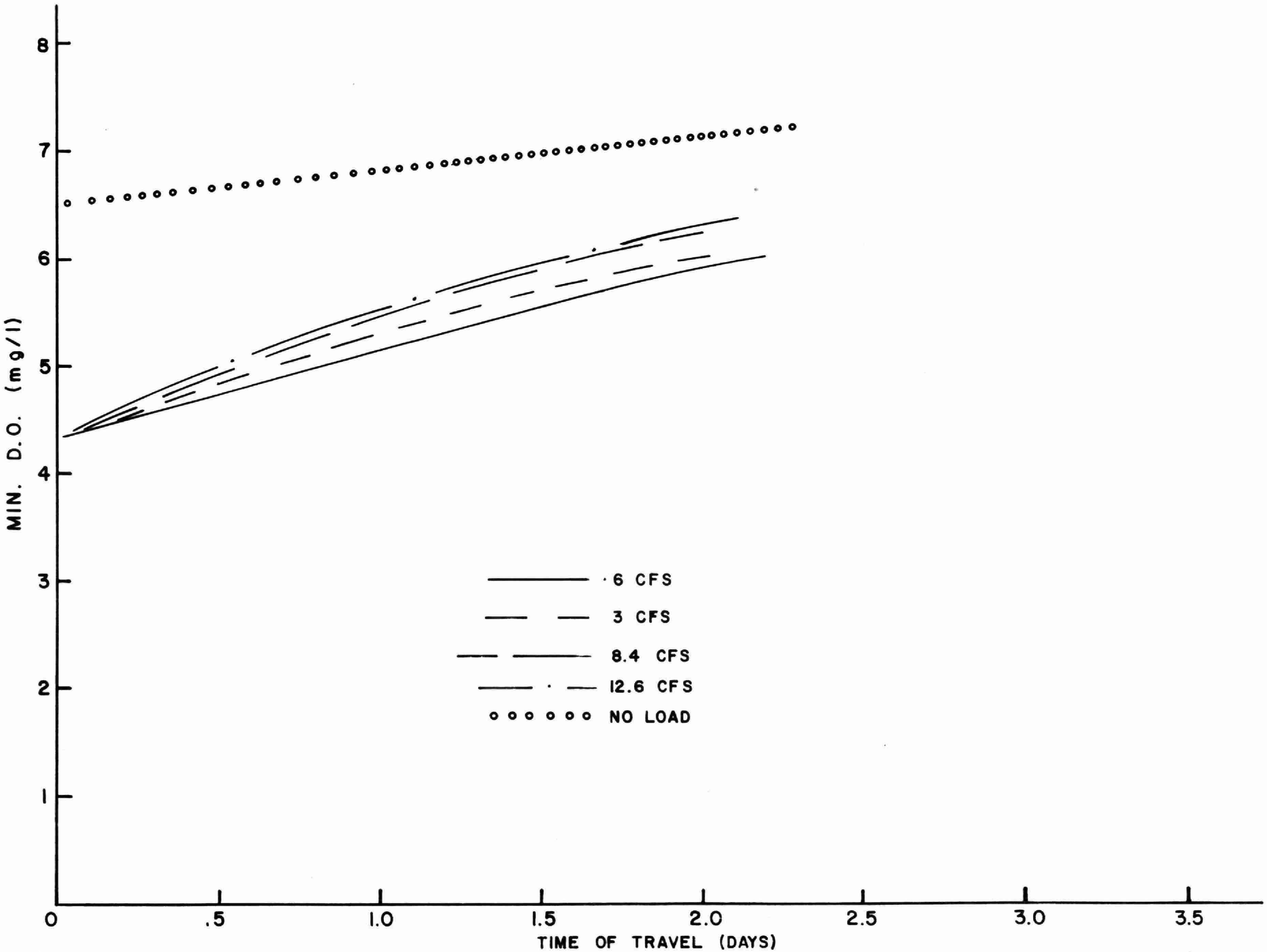

FIGURE 16 MINIMUM DISSOLVED OXYGEN LEVELS (mg/l) EXPECTED IN KETTLE CREEK UNDER FOUR STREAMFLOW REGIMES WITH TREATMENT TO 5mg/l BOD_5 & UNDER A 'NO-DISCHARGE' CONDITION AT ST. THOMAS.

expected to reach 3 cfs 10% of the time. With treatment to 10 mg/ℓ BOD_5, dissolved oxygen levels in Kettle Creek could be expected to fall below 3 mg/ℓ at lower flows and below 4 mg/ℓ even under the higher flow regimes.

With treatment to 5 mg/ℓ BOD (225 pounds per day BOD) it is apparent (Figure 16) that minimum levels would not fall below 4 mg/ℓ and that the desired guideline of 5 mg/ℓ would be met under all flow regimes one day of travel downstream from the source. However, the 1:1 dilution ratio will not always be achieved; in fact, during the critical June to October period, streamflows are expected to be lower than the required 8.4 cfs 60% of the time.

It is apparent then that although dissolved oxygen criteria may be achieved simply by improving the degree of treatment, this approach is not completely satisfactory for other reasons and must be considered an interim solution until another more suitable alternative is adopted. To achieve water quality objectives at existing design sewage flow, one of the following alternatives must be adopted:

1. Waste storage when streamflows are inadequate to provide a 1:1 dilution ratio and subsequent discharge when adequate streamflow is available.

2. Streamflow augmentation.

3. Exportation of wastes to Lake Erie.

Alternative 1:

To obtain an approximation of volume of storage required to ensure that discharge occurred only when streamflow equalled or exceeded sewage flows, a mass curve analysis was employed. As illustrated in Figures 17 and 18, a cumulative total of monthly mean streamflows was plotted for the 8 years of records. Plotted against the resultant curve was a line representing the volume of dilution required for various forms of treatment. Where the rate of increase in cumulative streamflow was less than the slope of the dilution line, storage was required.

From this curve and as summarized in Table 8 it appears that roughly 1320 acre-feet of storage is required at present design flow to meet the 1:1 dilution guideline. This figure translates to a lagoon approximately 265 acres in surface area assuming a 5 foot depth of storage. Depending upon the distribution of flows in any particular year, the amount of storage required may be higher.

Alternative 2:

A review of the possibility of streamflow augmentation was beyond the scope of this study but following a superficial review, it would appear that adequate augmentation may be available if at least one potential upstream flood control reservoir is developed. In its Kettle Creek Conservation Report of 1967, the Conservation Authorities Branch investigated three reservoir

Table 8 - Results of "mass curve" analysis - Kettle Creek at St. Thomas

TYPE OF TREATMENT	ASSUMPTIONS: SEWAGE EFFLUENT BOD (ppm)	BOD UPSTREAM (ppm)	AVERAGE DAILY EFFLUENT (cfs)	RATE OF STREAMFLOW REQUIRED FOR DILUTION OF THE EFFLUENT (cfs)	NUMBER OF MONTHS OF STORAGE REQUIRED (MONTHS)	STORAGE VOLUME REQUIRED FOR SEWAGE EFFLUENT (ACRE-FT.)
1. Secondary Sewage Plant	15	2	8.4	46	7	3,557
2. Secondary Sewage Plant	10	2	8.4	25	6	3,049
3. Tertiary Sewage Plant	5	2	8.4	8.4	3	1,321

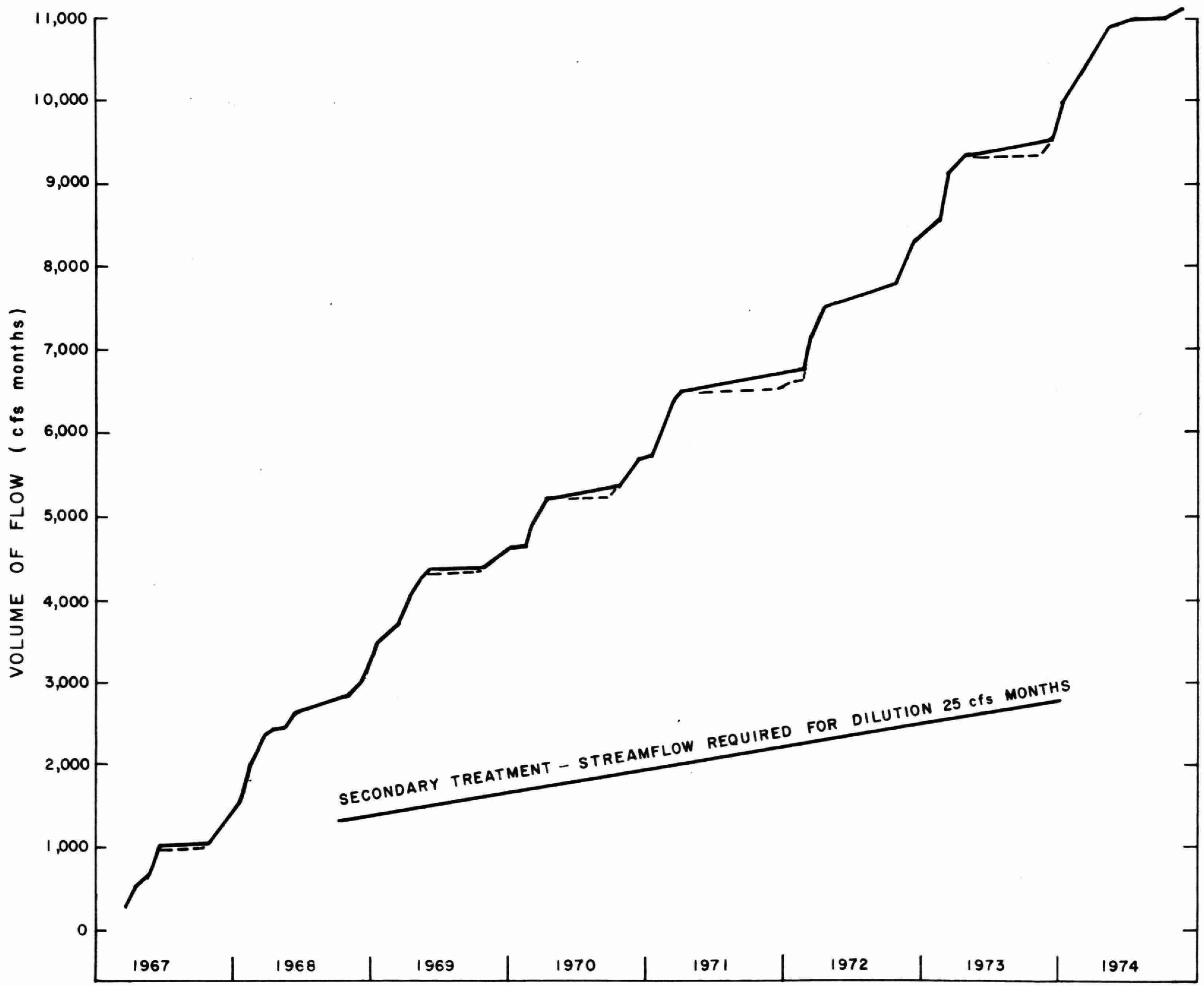

FIGURE 17: STORAGE ANALYSIS ILLUSTRATING THE CUMULATIVE TOTAL OF MONTHLY MEAN RUNOFF FROM 1967 – 1974 AND THE VOLUME REQUIRED TO DILUTE WASTES TREATED TO 10 mg/l BOD_5

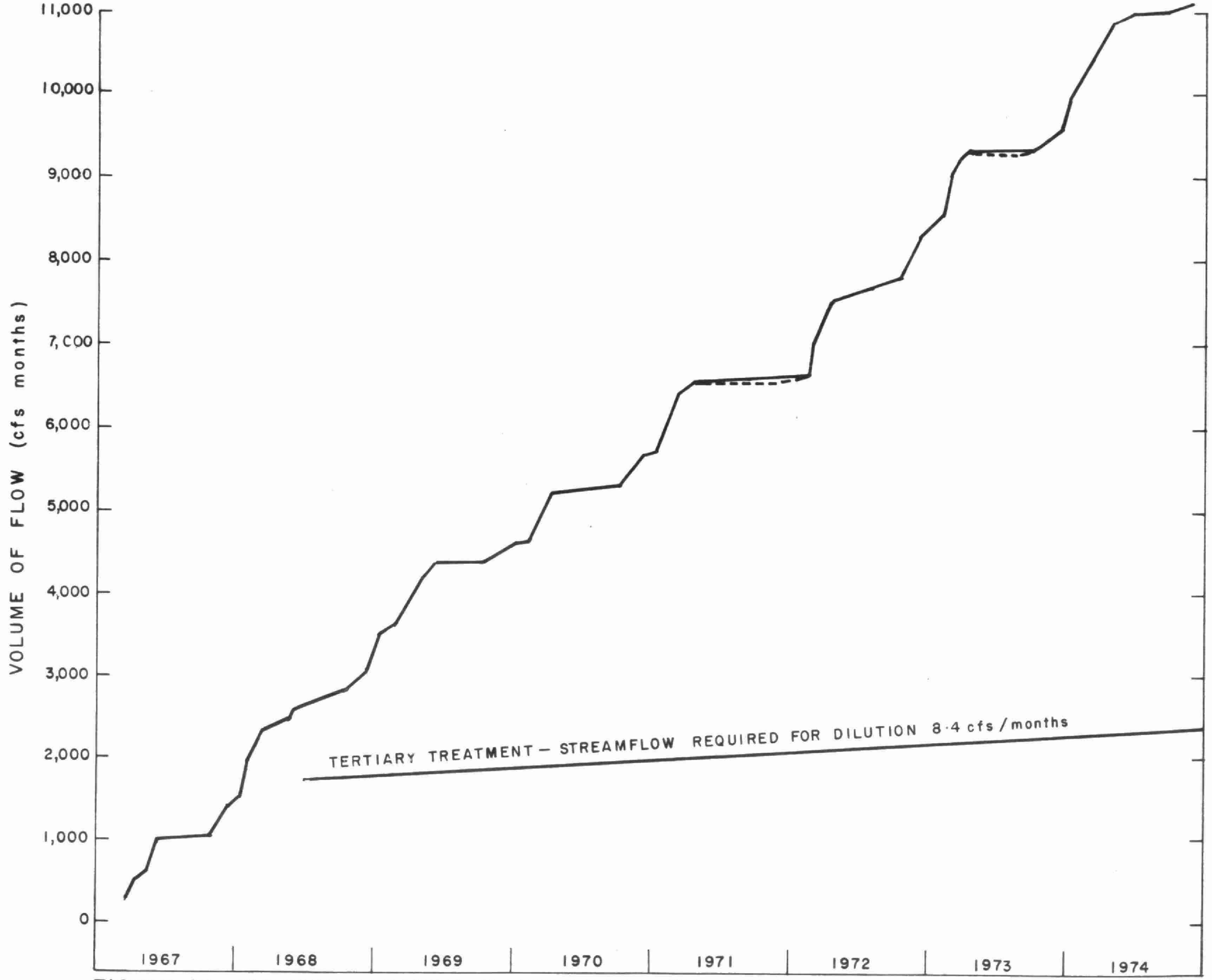

FIGURE 18: STORAGE ANALYSIS ILLUSTRATING THE CUMULATIVE TOTAL OF MONTHLY RUNOFF FROM 1967 — 1974 AND THE VOLUME REQUIRED TO DILUTE WASTES TREATED TO 5 mg/l BOD_5

sites - two small impoundments on upper Kettle Creek (O'Dell and Spring Creek reservoirs) and one larger reservoir on the lower reaches of Dodd Creek. Based on the lowest streamflow year (1971) on record at St. Thomas, low flow augmentation at a rate of 4.2 cfs would be required for 150 days from June through October to dilute the 8.4 cfs of tertiary treated wastes from St. Thomas at a 1:1 ratio. Although both the O'Dell and Dodd Creek reservoirs would afford the 1250 acre-foot volume required to produce the necessary flow, only the Dodd Creek structure could provide both flood storage and augmentation by increasing conservation storage by roughly 500 or 600 acre-feet.

It is reported that 2 abandoned municipal wells - the MacKenzie and McQuigan wells - are not presently in use and that theoretically they could augment streamflow by approximately 1 to 2 cfs if the water could be routed to Kettle Creek. At best, this additional flow plus the natural background would afford only about one half that required for adequate dilution purposes.

Alternative 3:

Waste exportation to Lake Erie is probably the most satisfactory, long-range solution to waste treatment problems in St. Thomas. Considered in a regional context, this alternative corresponds closely with long-term treatment requirements for the City of London (Water Management Study - Thames River Basin, 1975) and such a solution would be mutually beneficial to both municipalities. As indicated in earlier figures, the no-discharge approach is the most suitable option from the point of view of

the dissolved oxygen regime in Kettle Creek downstream from St. Thomas.

Expansion beyond existing design in all of these alternatives but the last would involve either an increase in waste storage or in low flow augmentation capabilities. Nonetheless, the City of St. Thomas should proceed immediately to upgrade its level of sewage treatment to include BOD reductions to 5 mg/ℓ and nitrification. To optimize plant operation and eliminate plant bypasses, the existing sewer separation program should continue. The City should examine the various alternatives suggested to determine the one most economically and practically feasible and press for its development.

Village of Port Stanley

At the present population of Port Stanley (1660), existing lagoons have the capacity to retain one year's waste flow and discharge safely in the spring. As design population is approached, storage following emptying in the spring could occur for as long as possible into the year and discharge at a rate equalling inflow could take place from fall through spring at which time the lagoons could again be emptied.

At the design population of 4400, six month's retention from May through October will be necessary. From November through April, continuous discharge at a rate equalling inflow is allowable and the lagoons may be emptied in March and April during spring high flows. This operational mode ensures a streamflow to sewage ratio of at least 10:1 year-round.

REFERENCES

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Ontario Department of Energy and Resources Management, Conservation Authorities Branch, Kettle Creek Conservation Report, 1967.

Ontario Ministries of the Environment and Natural Resources - Water Management Study, Thames River Basin, 1975.

Ontario Water Resources Commission, Wastewater Assimilation Study, Kettle Creek, 1966.

APPENDIX A

Illustration of Hydrological Data

Figure I -	Minimum 7-day average streamflow for 1967 - 1974 for Kettle Creek at St. Thomas
Figure II -	Minimum 1, 7, 15 and 30-day average streamflow from 1967-1974 for Kettle Creek at St. Thomas
Figure III-	Duration curve of daily flow for Kettle Creek at St. Thomas, January to December 1968-1973
Figure IV -	Duration curve of daily flow for Kettle Creek at St. Thomas, June to October, 1968-1973

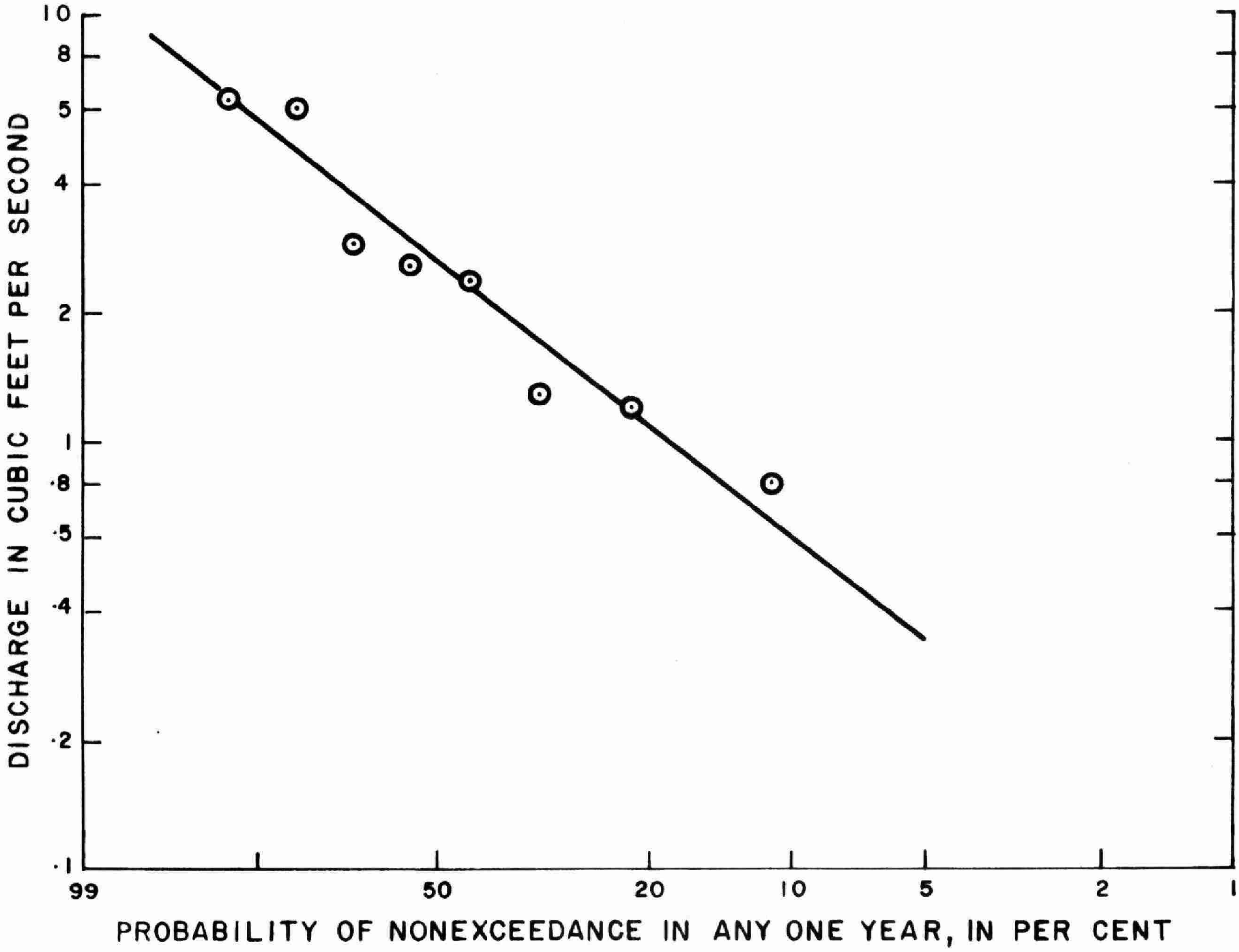

FIGURE I: MINIMUM 7-DAY AVERAGE STREAMFLOW FROM 1967-1974 FOR KETTLE CREEK AT ST. THOMAS

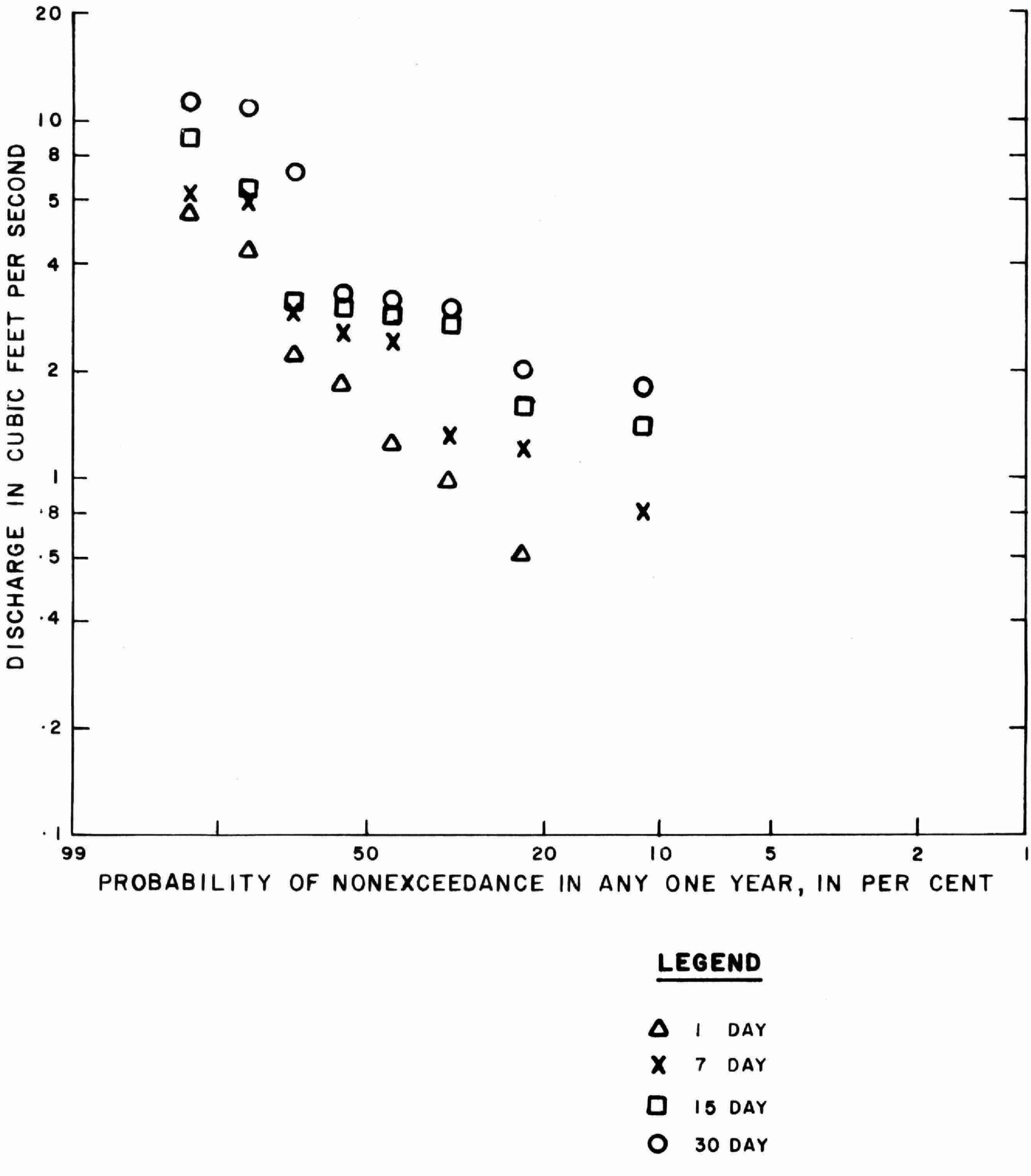

FIGURE II: MINIMUM 1,7,15 & 30-DAY AVERAGE STREAMFLOW FROM 1967-1974
FOR KETTLE CREEK AT ST. THOMAS

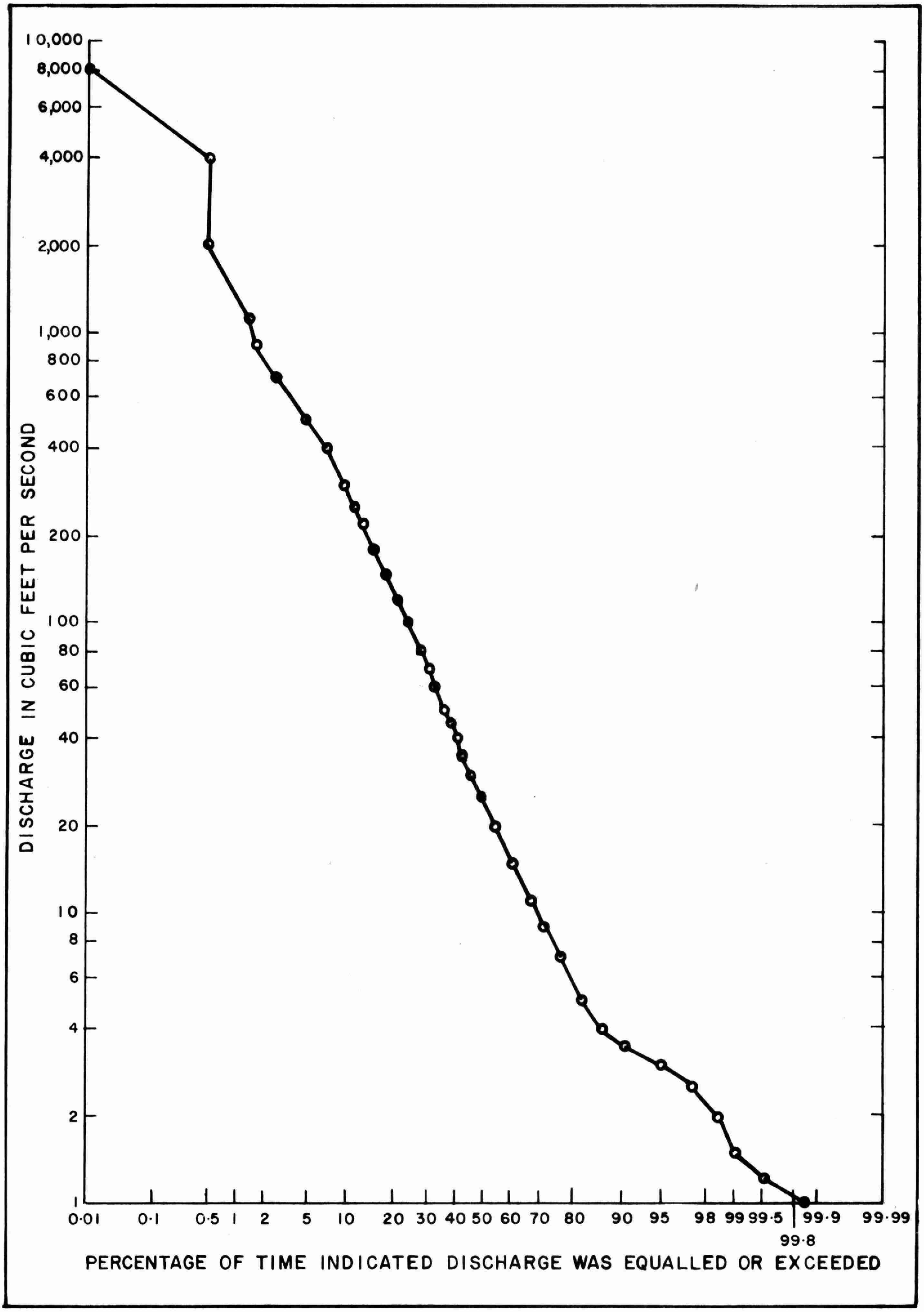

FIGURE III: DURATION CURVE OF DAILY FLOW FOR KETTLE CREEK AT ST. THOMAS, STATION Nº 02GC002 JANUARY TO DECEMBER, 1968 TO 1973

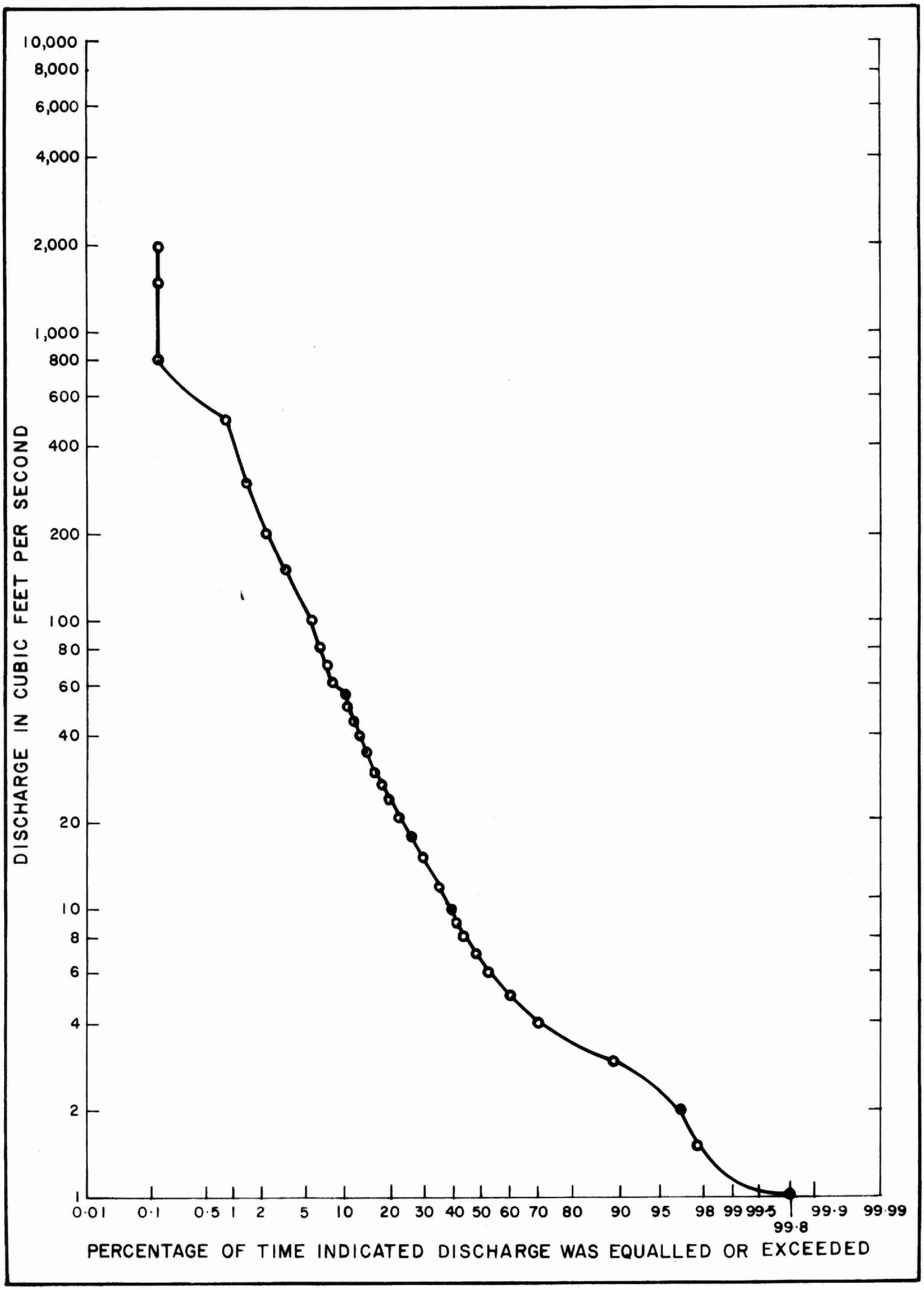

FIGURE IV: DURATION CURVE OF DAILY FLOW FOR KETTLE CREEK AT ST. THOMAS, STATION № 02GC002 JUNE TO OCTOBER, 1968 TO 1973

APPENDIX B

Tabulation of Biological Data

Table I	-	Number and species of fish collected at stations in the Kettle Creek Watershed - May & June 1973
Table II	-	Checklist of aquatic macroinvertebrates collected from the Kettle Creek Watershed - May, 1973
Table III	-	Number and types of aquatic macroinvertebrates collected from Kettle Creek Watershed - May, 1973
Table IV	-	Types and numbers per square foot of aquatic macroinvertebrates collected at 7 stations on Dodd Creek, summer, 1973

Table I - Numbers and species of fish collected at 16 stations on the Kettle Creek Watershed - May and June, 1973. (Methods outlined in text)

SPECIES	KC2	KC4	KC5	KC14	KC28	KC29	KC36	KC38	KC40	UNC	DC16	DC18	DC19	DC21	DC22	DC25
Common Shiner	60	26	68		1	20	19		1	5	6	3	36	23	18	6
Rosyface Shiner			42													
Sand Shiner					1											1
Creek Chub	16	8	9		1		10			2	9	2	17	2	1	
Hornyhead Chub	8		2													
White Sucker	6		1			9	6	6	3	6	11		13		3	1
Bluntnose Minnow	7	1	8		1	1			2		1				1	
Fathead Minnow												2		1		
Brown Bullhead																
Channel Catfish									1							
Stonecat	1															
Black Crappie				4		7										
Rockbass	1		1												1	1
Smallmouth Bass			1													
Largemouth Bass						1										
Silverbass								1	1							
Carp						P	P	25+	P							
Northern Pike											1					
Johnny Darter	4										3					1
Blackside Darter	1					1									2	
Brook Stickleback											4			9		
Alewife							P									
NO. OF SPECIES	9	3	8	1	4	7	5	3	6	3	7	3	3	4	6	5
NO. OF INDIVIDUALS	104	35	132	4	4	39	35	32	8	13	35	7	66	35	26	10

Table II - Checklist of aquatic macroinvertebrates collected from the Kettle Creek Watershed, May 1973

Organisms	Upper Kettle Creek	Dodd Creek	Lower Kettle Creek
STONEFLIES			
<u>Alloperla</u>		X	
<u>Perlesta</u>		X	X
MAYFLIES			
<u>Baetis</u>	X	X	X
<u>Caenis</u>	X	X	X
<u>Heptagenia</u>		X	
<u>Paraleptophlebia</u>		X	
<u>Stenonema</u>	X	X	X
<u>S. tripunctatum</u>	X		X
CADDISFLIES			
<u>Cheumatopsyche</u>	X	X	X
<u>Helicopsyche</u>		X	X
<u>Hydropsyche</u>	X	X	X
<u>Hydroptila</u>	X		X
<u>Pycnopsyche</u>	X		
<u>Triaenodes</u>		X	
NEUROPTERA			
<u>Chauliodes</u>			X
LEPIDOPTERA			
<u>Paragyractis</u>		X	X
DAMSELFLIES			
Agrionidae			X
Coenagrionidae	X	X	X
DRAGONFLIES			
Aeshnidae		X	X
Libellulidae		X	
BEETLES			
Elmidae		X	X
Hydrophilidae			X
BUGS			
Corixidae	X		
MITES		X	
DIPTERA			
Chironomidae	X	X	X
Empididae			X
Simuliidae	X	X	X

Table II - Continued.....

Organisms	Upper Kettle Creek	Dodd Creek	Lower Kettle Creek
ISOPODS			
Asellus		X	X
Lirceus		X	
AMPHIPODS			
Hyalella	X	X	X
Gammarus		X	X
Crangonyx		X	
CRAYFISH			
Orconectes immunis	X		
Orconectes propinquus	X	X	X
CLAMS			
Sphaerium	X	X	X
Pisidium		X	X
Unionidae		X	
SNAILS			
Ferrissia			X
Helisoma	X	X	
Gyraulus		X	
Lymnaea		X	X
Physa	X	X	X
FLATWORMS	X	X	X
LEECH			
Erpobdellidae		X	X
Helobdella stagnalis	X	X	
Placobdella	X		
Glossiphoniidae		X	
WORMS			
Lumbriculidae	X		X
Naididae			X
Tubificidae	X	X	X
TOTAL TAXA	23	37	33

Table III - Numbers and types of aquatic macroinvertebrates collected at 19 stations on Kettle Creek and 1 station on Union Creek - Summer 1973
(Numbers per foot square)

ORGANISMS	KC2	KC4	KC5	KC7	KC13	KC14	KC27	KC28	KC29	KC33 L R	KC36	KC38	KC40	KC41*	KC42* L R	KC43*	KC44*	UNC
STONEFLIES																		
Perlesta								1										
MAYFLIES																		
Baetis	18		13	10	11	10	46	2	15	54		1	11					32
Caenis	P		2	1	1	P	P	P	P			P						P
Stenonema	P	2		2		P	P	1	P	P								1
S. tripunctatum	P				1	P	P	P	P									
CADDISFLIES																		
Cheumatopsyche	51			P				2	1									6
Helicopsyche								P										
Hydroptila	1							1	3				2					
Hydropsyche	25		2	8		5	1	62	14	4	1	P	9					48
Pycnopsyche	P																	
pupae	36	1		7	P	15	P	44	4	4	1	1	14					13
NEUROPTERA																		
Chauliodes																		1
LEPIDOPTERA																		
Paragyractis								2	1									P
DAMSELFLIES																		
Agrionidae						P												P
Coenagrionidae	P	P	P	P	P	P	P	P			P							P

Table III - Continued.....

ORGANISMS	KC2	KC4	KC5	KC7	KC13	KC14	KC27	KC28	KC29	KC33 L R	KC36	KC38	KC40	KC41*	KC42* L R	KC43*	KC44*	UNC
DRAGONFLIES																		
Aeshnidae																		P
BEETLES																		
Elmidae					4		2	1	1									4
Hydrophilidae											1							
Unident adults	13		P	5	4	P	1	3	P	1		6	1					32
BUGS																		
Corixidae			P															
DIPTERA																		
Chironomidae	18	2	5	1	7	20	23	11	4	13	32	22	1			1	121	46
Empididae						1												
Simuliidae	16		2		112	145	93	11	37	62	14	36	1					10
pupae	8		1	1	7	10	6	8	1		1	2	1					
ISOPODS																		
Asellus									P									
AMPHIPODS																		
Hyallela	P		P	P	1	1	P	P										
Gammarus												P	1					36
CRAYFISH																		
Orconectes immunis		P																
O. propinquus	P					P		P	P	P	P		P					

Table III - Continued.....

ORGANISMS	KC2	KC4	KC5	KC7	KC13	KC14	KC27	KC28	KC29	KC33		KC36	KC38	KC40	KC41*	KC42*		KC43*	KC44*	UNC
										L	R					L	R			
CLAMS																				
Sphaerium	1			P	14	P	1	2	3					P				1	11	
Pisidium								1	1										1	
SNAILS																				
Ferrissia																				4
Helisoma		3																		
Lymnaea							1					1								
Physa			P	P	P				P			P	P							
FLATWORMS	1								1											
LEECH																				
Erpobdellidae							1		P				1						3	
Helobdella stagnalis	P																			
Placobdella		P	P																	
WORMS																				
Lumbricalidae	P								1											
Naididae							7													
Tubificidae		16	P		P	15	2	1	8			P	9	P	35	247	13	990	32	3
NO. OF TAXA	18	8	13	11	12	15	14	20	20	7	0	9	10	10	1	1	1	3	5	16
NO. OF ORGANISMS	130	23	24	22	141	197	170	105	90	133	0	49	69	25	35	247	13	992	167	191

* Ponar Dredge Samples

Table IV - Types and numbers per square foot of aquatic macroinvertebrates collected at 7 stations on Dodd Creek, Summer 1973

Organisms	D.C.#16	D.C.#18	D.C.#19	D.C.#21	D.C.#22	D.C.#25	D.C.#26
STONEFLIES							
Alloperla	4			5	P		P
Perlesta				3	1	1	
MAYFLY							
Baetis	P			1	P	8	P
Caenis	P	1		P		5	
Heptagenia				2		2	
Paraleptophlebia				P			
Stenonema	2					P	9
CADDISFLIES							
Cheumatopsyche	2					3	13
Helicopsyche						41	1
Hydropsyche						40	77
Triaenodes						P	
Unident pupa	8	1			P	42	53
DAMSELFLIES							
Coenagrionidae	7	P	P		P		P
DRAGONFLY							
Aeschnidae	P						
Libellulidae	P						

Table IV - Continued.....

Organisms	D.C.#16	D.C.#18	D.C.#19	D.C.#21	D.C.#22	D.C.#25	D.C.#26
LEPIDOPTRA							
Paragyractis							4
BEETLES							
unident adults	P		P	P	P	9	3
Elmidae						6	6
MITES					1		
DIPTERA							
Chironomidae	20	5	7	6	5	66	59
Simuliidae				7	104	11	P
unident pupa			2	8	1	4	
ISOPODS							
Asellus					P		
Lirceus				P			
AMPHIPODS							
Crangonyx	1						
Gammarus				2			
Hyalella	2	P	P	P	P		P

Table IV - Continued.....

Organisms	D.C.#16	D.C.#18	D.C.#19	D.C.#21	D.C.#22	D.C.#25	D.C.#26
CRAYFISH							
Orconectes propinquus	P	P					
CLAMS							
Sphaerium	P	1				16	1
Pisidium						P	
Unionidae				P	P	P	
SNAILS							
Helisoma			P				
Gyraulus	P			P			
Lymnaea	P	P					
Physa	1	1	P				
FLATWORMS					1	2	P
LEECH							
Erpobdellidae					P		
Helobdella stagnalis	P						
Glossiphoniidae		P	P				

Table IV - Continued.....

Organisms	D.C.#16	D.C.#18	D.C.#19	D.C.#21	D.C.#22	D.C.#25	D.C.#26
WORMS							
Tubificidae	1	540	9	1	11	3	2
TOTAL TAXA	19	11	8	15	15	17	15
No. of Organisms	40	548	16	27	123	213	175

TOTAL TAXA 37